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Analysis of the Coupled Assessment of Ecosystem Health and Its Spatial and Temporal Evolution in Fujian China

Delong Cao [1,3], Tingyuan Tang [2], Shuang Wang [1], Shixian Hu [4], Sa Gen [1,3], Siping Wu [3] and Zhen Lin [1,3,] *

[1] Academy of Ecological Civilization, Beijing Forestry University, Beijing 100083, China; dron_tsao@bjfu.edu.cn(D.C.);linzhen66@bjfu.edu.cn(Z.L.);work.wangshuang@foxmail.com(S.W.); 95270985@qq.com(S.G.)
[2] Beijing Institute of Surveying and Mapping, Beijing 100038, China; TangtyRS@126.com(T.T.)
[3] School of Marxism, Beijing Forestry University, Beijing 100083, China; dron_tsao@bjfu.edu.cn(D.C.);linzhen66@bjfu.edu.cn(Z.L.); 95270985@qq.com(S.G.); wusiping21@163.com(S.W.)
[4] School of Management, Shanghai University of Engineering Science，Shanghai 201620，China；hushixian2@163.com(S.H.)
* Correspondence: linzhen66@bjfu.edu.cn; Tel.: +86-17701309565

Abstract: As the first pilot ecological civilization zone in China, Fujian Province has an excellent ecological environment quality, and its ecological environment-related indices continue to be among the highest in the country. In order to investigate the causes of the excellent ecological quality in Fujian Province in the past 15 years, this paper selects MODIS images, land use data and provincial and municipal statistical yearbook data of Fujian province from 2005 to 2020 as data sources, evaluates the ecological system health of Fujian Province by remote-sensing ecological index (i.e. RSEI), constructs the land use intensity system of Fujian Province at the same time, and uses a coupled coordination model to analyze the coupling between RSEI and The coupled coordination model was used to analyze the coupling relationship between RSEI and land use intensity, and finally the spatial and temporal evolution of ecological health in Fujian Province from 2005 to 2020 was analyzed. The results show that the coupled coordination between land use intensity and ecosystem health in Fujian province showed a continuous increase between 2005 and 2020, especially in Ningde, where the increase was most significant, from 0.0993 to 0.963, this pattern of spatial distribution is lower in the south-eastern coastal region than in the north-western interior, higher in the south-western region than in the north-western region, and higher in the north-eastern region than in the south-eastern region. In terms of the type of role, the land use intensity of most cities in Fujian Province in 2005 played an obvious role in blocking the degree of ecosystem health, but as time changed, urban land use continued to be optimized and reached moderate or even high quality coordination with the quality of the ecological environment, but Xiamen City developed relatively slowly and its 2020 coupling degree value was 0.315, which was still in mild disorder. This study fills a gap in the research mechanism of the interaction between the degree of ecosystem health and land use intensity, and also provides a new perspective for the construction of ecological civilization and the assessment of the degree of ecosystem health in Fujian Province and the whole country.

Keywords: Fujian; coupling and coordination mechanism; intensity of land use; extent of ecosystem health; quality of the ecosystem

1. Introduction

With the deepening of the new urbanization layout, "stable and healthy ecosystem" and "harmonious coexistence between human and nature" are increasingly becoming important elements of the new urbanization development, and human beings are in urgent need of an environmentally friendly new ecosystem that focuses on sustainable development goals, promotes harmonious coexistence between human and nature, and is We need a new type of environment-friendly

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ecosystem that is in between the historical ecosystem and the man-made ecosystem to meet the challenges of the coupled social-economic-environmental sustainable development[1]. It is obvious that Lao Tzu's "The Way of Nature" is no longer sufficient to describe the natural world today, and the simple call to return to nature can no longer conceal the impact of human beings on nature[2]. Economic development and ecological protection are equally important, but how to deal with the complex ecological challenges brought about by the process of economic development has also become a key issue that requires attention. The coupling of "society-economy-environment" is not simply a return to nature, nor is it simply a high-tech cloak, nor is it a unified ecological governance, but rather it focuses on the synergistic benefits of the three in the process of working together, and this coordination can use the power of science and technology to re-establish mankind's understanding of the system of nature, and use nature itself, adopting the power of nature to gradually replace artificial technology and promote the harmonious coexistence of man and nature, thus realizing the great ambition of ecological civilization.

Since the 1970s, the evaluation of ecosystem health has gradually become a hot topic of research in domestic and international academia, and the number of studies related to ecosystem health has gradually increased, but most of the studies only assessed ecosystem health qualitatively or quantitatively based on a single dimension or a specific dimension, such as the use of Normalized Difference Vegetation Index (NDVI)[3–5], Leaf Area Index (LAI)[6,7] and Net Primary Productivity (NPP)[6,7]. Difference Vegetation Index (NDVI)[2,4,5], Leaf Area Index (LAI)[6,7], and Net Primary Productivity (NPP)[8] to assess vegetation growth; urban heat island monitoring based on surface temperature detection in the thermal infrared band of remote sensing images[9]; and construction of various drought indices to assess regional drought conditions[10–12]. Due to the complexity of ecosystems, a single index often does not provide a comprehensive and effective assessment and description of ecosystems[13]. Remote sensing technology has the advantages of wide-scale monitoring, periodicity and real-time assessment, and is widely used for ecosystem health degree evaluation, while remote sensing-based ecological index methods use principal component analysis coupled with NDVI[14,15], Wetness Index (WET)[16], dryness (the Normalized Difference Based built and Impervious Surface Index, NDBSI)[17,18] and heat (Land Surface Temperature, LST) four ecological indicators, which can systematically evaluate the health of regional ecosystems[19,20]. The biggest problem in the Anthropocene is how to deal with the coupling of "society-economy-environment", and society, economy and environment have become an inseparable research whole. To quantify the relationship between regional ecological environment and economic development, Lu Yu used STIRPAT (stochastic impacts by regression on population, affluence, and technology) with indicators such as ecological stress index, ecological coordination coefficient, and ecological footprint diversity index. extended model combined with principal component regression model to analyze the main drivers of 3D ecological footprint evolution; Xiong Xi introduced the European Environment Agency's DPSIR (i.e., driver-pressure-state-impact-response) environmental management model into its ecological civilization construction analysis evaluation[21], using rough set theory and methods to carry out analysis and evaluation regarding its ecological civilization construction; Xin constructed a land use intensity indicator system and a coupled coordination degree model to explore the relationship between ecological service value and land use intensity and the reasons for their changes[22]. Therefore, in order to evaluate the ecosystem health of Fujian Province more comprehensively, it is necessary to explore the comprehensive impact of social and economic development on the ecological environment, and this paper will construct a land use intensity system in Fujian Province from the social and economic dimensions.

To summarize, this paper takes the whole province of Fujian Province and the municipalities as the study area, adopts MODIS images, habitat data and land use data from 2005 to 2020 as well as statistical yearbooks and ecological yearbooks at all levels in Fujian Province as data sources, (1) constructs the ecological health of the whole Fujian Province from 2005 to 2020 using RSEI indicators, and conducts spatial and temporal analysis; (2) constructs the Fujian Province (2) to construct a land use intensity system in Fujian Province and conduct spatial and temporal analysis on the impact of social and economic development on ecological environment in Fujian Province; (3) to construct a coupled coordination model using RSEI and land use intensity to explore the relationship between RSEI and land use intensity and the reasons for their changes.

2. Materials and Methods

2.1 Study Area

Fujian Province (115°50′-120°40′E ,23°33′-28°20′N) is located in the southeastern coastal region of China, bordering Zhejiang Province, Jiangxi Province and Guangdong Province. The province has jurisdiction over nine municipalities, including Fuzhou, Xiamen, Zhangzhou, Quanzhou, Sanming, Putian, Nanping, Longyan, and Ningde, with an area of about 124,000 km^2 and a resident population of 41.61 million (as of 2020)[23]. The terrain in Fujian province is complex, with river valleys and basins in the central and western parts, hills and coastal plains along the eastern coast, and generally high in the northwest and low in the southeast. The climate of Fujian province is typical of subtropical maritime monsoon climate, with abundant rainfall and sufficient light, which is suitable for human settlement and plant growth[24]. According to the Ecological Environment Department of Fujian Province from 2001 to 2020, the ecological environment of Fujian Province is at an excellent level and the ecological condition index continues to be among the top in the country.

As one of the first provinces in China to carry out ecological construction, Fujian Province has incorporated resource consumption, environmental damage, and ecological benefits into its economic and social development evaluation system since 2000, but there are still problems that need to be solved in the process of ecological governance practices[25,26]; therefore, this paper takes the whole province of Fujian Province as the main research object and conducts sub-city Therefore, this paper takes the whole province of Fujian Province as the main research object, and conducts data collection and analysis by localities, in order to provide theoretical support and technical support for ecological civilization construction in Fujian Province.

2.2 Material

In order to monitor and analyze the ecological environment dynamics in Fujian Province, this paper uses various data sources such as MODIS images, land use data and economic data of Fujian Province in 2005, 2010, 2015 and 2020.

MODIS images were used to constitute a MODIS dataset with four time (2005, 2010, 2015, 2020), spatial resolution of 500 m, and three products (MOD091, MOD11A2, MOD13A1) in the GEE platform[27], and the GEE platform was used to calculate the RSEIs of the study area for 2005, 2010, 2015, and 2020 RSEI.

The land use data of Fujian Province were obtained from Wuhan University to produce the 1990-2020 Chinese land cover dataset on the GEE platform, including eight types of cropland, forest land, shrubs, grassland, water, snow and ice, construction land, and wetlands. In order to fully calculate the value of ecosystem services in the study area, this paper used ArcGIS (10.5) to reclassify the land cover dataset of Wuhan University, and used the spatial statistical analysis tool of ArcGIS to calculate the reclassified land area on a raster scale (500m × 500m), and finally obtained five different types of arable land, watershed, grassland, woodland, and construction land use types. Other socio-economic data were obtained from the statistical yearbooks, ecological yearbooks and environmental annual reports at all levels in Fujian Province and the municipalities.

2.3 Methods

In order to study the ecological environment changes in Fujian Province from 2005 to 2020 and evaluate the effectiveness of ecological management in Fujian Province in the past 15 years, this paper firstly uses the GEE platform to calculate the RSEI of the study area in 2005, 2010, 2015 and 2020 with MOIDS images and conducts spatial and temporal analysis; secondly, analyzes the land use status of the study area by constructing a land use intensity index system; finally, explores the relationship between RSEI and land use intensity by constructing a coupled coordination model between the two, the flow chart of which is shown in Figure 2.

2.3.1 RSEI calculations

In order to conduct large-scale remote sensing environmental monitoring, this paper uses low- and medium-resolution MODIS images to calculate RSEI. The RSEI [28,29]index is an index based on remote sensing information and natural factors established based on greenness, humidity, heat and dryness indicators. The vegetation normalized index [14] was used for the greenness index, the land surface temperature for the heat index, the humidity index [16] for the humidity index, and the dryness index [17,18] for the dryness index with the following equations (1)-(3).

For the calculation of RSEI, considering that there are more water bodies in the study area will cause the results to be imaged, firstly, the MNDWI index [30,31] needs to be used to extract the water body threshold for water body masking, then the four indices of NDVI, LST, WET, and NDBSI are calculated and normalized separately (Equation (4)), and finally, Principal Component Analysis (PCA) is used Analysis (PCA) [32]was used to analyze the normalized indices and weighted the calculation using the first component as the weight of each index (Equation (5)). In order to better reflect the ecological health of Fujian Province using the RSEI indicators as well as for spatial analysis, the RSEI was divided into five grades: worst (0-0.2), poor (0.2-0.4), fair (0.4-0.6), good (0.6-0.8) and good (0.8-1) with reference to the ecological environment grading criteria in the Technical Specification for Ecological Evaluation, as shown in Table 1.

$$NDVI = (NIR_1 - Red)/(NIR_1 + Red) \tag{1}$$

$$WET = 0.1147 * Red + 0.2489 * NIR_1 + 0.2408 * Blue + 0.3132 * Green - 0.3122 * NIR_2 - 0.6416 * SWIR_1 - 0.5087 * SWIR_2 \tag{1}$$

$$IBI = \frac{\frac{2 * SWIR_1}{SWIR_1 + NIR_1} - \left[\frac{NIR_1}{NIR_1 + Red} + \frac{Green}{Green + SWIR_1}\right]}{\frac{2 * SWIR_1}{SWIR_1 + NIR_1} + \left[\frac{NIR_1}{NIR_1 + Red} + \frac{Green}{Green + SWIR_1}\right]}$$

$$SI = \frac{[(SWIR_1 + Red) - (NIR + Blue)]}{[(SWIR_1 + Red) + (NIR + Blue)]}$$

$$\mathrm{NDBSI} = \frac{IBI + SI}{2} \tag{2}$$

Where NIR_1 indicates near-infrared band 1 reflectance, Red indicates red band reflectance, Blue indicates blue band reflectance, Green indicates rate band reflectance, NIR_2 indicates near-infrared band 2 reflectance, $SWIR_1$ indicates short-wave infrared band 1 reflectance, $SWIR_1$ indicates short-wave infrared band 2 reflectance, IBI indicates building index, and SI indicates soil index.

$$NI_i = (I_i - I_{min})/(I_{max} - I_{min}) \tag{3}$$

Where NI_i denotes the normalized result of each index, I_i is the individual value of each index, and I_{max} and I_{min} are the maximum and minimum values of each index, respectively.

$$RSEI_0 = 1 - PC_1 * [f(NDVI, WET, LST, NDBSI)]$$

$$RSEI = (RSEI_0 - RSEI_{0min})/(RSEI_{0max} - RSEI_{0min}) \tag{4}$$

Where $RSEI_0$ represents the initial value of the ecological index; PC_1 represents the first component of the principal component analysis; $RSEI_{min}$ is the minimum value of RSEI and $RSEI_{max}$ is the maximum value of RSEI.

Table 1. Ecological quality rating scale.

RSEI Value	Grade
0-0.2	Worst
0.2-0.4	Bad
0.4-0.6	Normal

0.6-0.8	Good
0.8-1.0	Excellent

2.3.2 Calculation of land use intensity

In order to analyze and evaluate the land use changes in Fujian Province from 2005 to 2020, this paper refers to the experiments of Oehl[33], and the constructed index system for building land use intensity in Fujian Province includes three parts: land use structure, land investment and land use efficiency, and the specific index system is shown in Table 2. land use structure includes four indicators of arable land ratio, forest ratio, grassland ratio and construction land ratio, and land investment includes three indicators of crop sown area, fixed asset investment and employment. Land investment includes three indicators of crop sowing area, fixed asset investment and employment, and land use efficiency includes three indicators of grain production, GDP value, gross industrial output value and gross agricultural output value. In order to construct a land use intensity index that is consistent with Fujian, this paper first standardizes eleven indicators and then uses the entropy weight method to determine the weights of each indicator.

Table 2. Fujian municipal land use intensity indicator system.

		Types	Fujian	Fuzhou	Xiamen	Putian	Sanming	Quanzhou	Zhangzhou	Nanping	Longyan	Ningde
Land-use structure	Arable land ratio	+	0.00069	0.0646	0.1528	0.228	0.12	0.1922	0.1063	0.1254	0.146	0.1063
	Forest land ratio	+	0.00003	0.0915	0.068	0.0976	0.093	0.096	0.0737	0.0989	0.087	0.0737
	Grassland ratio	+	0.01224	0.0793	0.0816	0.0803	0.0804	0.0699	0.1025	0.0953	0.0766	0.1025
	Construction land ratio	+	0.00650	0.0774	0.0742	0.0722	0.0808	0.0749	0.0892	0.0925	0.0832	0.0892
Land investments	Crop sown coverage	+	0.24050	0.2037	0.1406	0.0651	0.0654	0.0678	0.0781	0.0633	0.07	0.0781
	Fixed asset investment	-	0.11981	0.0793	0.0691	0.0708	0.0753	0.0836	0.0833	0.0956	0.0791	0.0833
	Number of employed	+	0.13230	0.0837	0.0762	0.099	0.1373	0.065	0.0976	0.0711	0.0669	0.0976
Land-use efficiency	Grain production	-	0.10001	0.0634	0.0649	0.0695	0.1065	0.0861	0.0945	0.1112	0.1242	0.0945

Gross Domestic Product	+	0.13499	0.1017	0.102	0.0885	0.0911	0.0983	0.1136	0.0927	0.1014	0.1136
Gross value of industrial output	+	0.12327	0.0697	0.0721	0.062	0.0667	0.0713	0.0744	0.0704	0.0692	0.0744
Gross value of agricultural output	+	0.12967	0.0858	0.0988	0.0671	0.0835	0.0948	0.087	0.0834	0.0963	0.087

(a) When evaluating the research subjects of multi-factor indicators, the influence of different dimensions on the evaluation of the indicator data must be considered. Therefore, this paper will use the range transformation method to standardize the data under different dimensions, and the calculation method is as follows.

For positive indicators.

$$b_{i,j,t} = \frac{B_{i,j,t} - min(B_{i,j,t})}{max(B_{i,j,t}) - min(B_{i,j,t})} \quad i = 1,2,3,\ldots,m; j = 1,2,3,\ldots,n; t = 2005,\ldots,2020 \tag{6}$$

For negative indicators.

$$b_{i,j,t} = \frac{max(B_{i,j,t}) - B_{i,j,t}}{max(B_{i,j,t}) - min(B_{i,j,t})} \quad i = 1,2,3,\ldots,m; j = 1,2,3,\ldots,n; t = 2005,\ldots,2020 \tag{7}$$

Where $b_{i,j,t}$ denotes normalized values, $B_{i,j,t}$ denotes raw data, i denotes category, j denotes each indicator, and t denotes time.

(b) Entropy is a measure of system disorder, and information is a measure of system orderliness. If the information entropy of the index is smaller, the more information the index provides, the greater the role in the comprehensive evaluation, and the higher the weight should be[34]. Therefore, in this paper, the entropy-based method[35] will be used to determine the weights in the index system, and the weights of each index are shown in Table 2, and the calculation formula is as follows.

$$\begin{aligned} p_{i,j,t} &= \frac{b_{i,j,t}}{\sum_{i=1}^{m} b_{i,j,t}} \\ e_{j,t} &= \frac{-1}{ln(m) * \sum_{i=1}^{m} p_{i,j,t} * ln(p_{i,j,t})} \\ W_{j,t} &= 1 - \frac{e_{j,t}}{\sum_{i=1}^{m}(1 - e_{j,t})} \\ i &= 1,2,3,\ldots,m; j = 1,2,3,\ldots,n; t = 2005,\ldots,2020 \end{aligned} \tag{8}$$

Where $p_{i,j,t}$ denotes the proportion of class i indicator j at time t, $e_{j,t}$ denotes the information entropy of j indicator at time t, and $W_{j,t}$ denotes the weight of indicator j.

(c) Based on the weights of each indicator determined by the entropy weight method, the land use intensity is calculated and classified into classes, and the classification table is shown in Table 3.

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Table 3. Comparison table of coupling coordination thresholds.

D value interval of coupling coordination degree	Coordination level	Degree of coupling coordination
(0.0~0.1)	1	Extreme disorders
[0.1~0.2)	2	Serious disorders
[0.2~0.3)	3	Moderate disorders
[0.3~0.4)	4	Mild disorders
[0.4~0.5)	5	Proximal disorders
[0.5~0.6)	6	Barely coordination
[0.6~0.7)	7	Primary coordination
[0.7~0.8)	8	Mid-level coordination
[0.8~0.9)	9	Good coordination
[0.9~1.0)	10	Excellent coordination

2.3.3 Coupling coordination model

The coupling analysis model [36] is a measure of the degree of association between different modules. The more connections between modules, the stronger the coupling and the lower the independence. It was initially used mainly for software systems and has been used in other fields, such as environmental science and economics. In this paper, the correlation between land use intensity and ecosystem service value in Fujian Province is studied using the coupling coordination degree.

The equations of the model are as follows.

$$C_t = \frac{2\sqrt{Land_t * RSEI_t}}{Land_t + RSEI_t}$$
$$H_t = \sqrt{Land_t * RSEI_t} \quad (9)$$
$$T_t = \gamma * Land_t + \beta * RSEI_t$$

Where C_t denotes the degree of coupling, H_t denotes the degree of coordination between land use and RSEI in the study area, and T_t denotes the degree of coupling and coordination between land use and RSEI in the study area; t refers to time. In this paper, it is assumed that land use and RSEI play an equally important role in the integrated development of the study area, so $\gamma = \beta = 0.5$.

In order to better reflect the coupling coordination relationship, this paper classifies the coupling coordination degree between land use intensity and ecological environment quality in the study area, as shown in Table 3.

3. Results

3.1 Spatial and temporal analysis of ecological environmental quality in Fujian Province from 2005 to 2020 based on RSEI

According to the RSEI calculation model in Section 2.1, the RESI distribution map (Figure 3) and rank map (Figure 4) of Fujian Province from 2005 to 2020 are derived in this paper, and this section mainly describes the spatial and temporal analysis of the ecological environmental quality status in Fujian Province.

From 2005 to 2020, the ecological environmental quality condition in Fujian Province has continued to improve, and the average value of RSEI in 2010, 2015 and 2020 is above 0.7, among which the ecological environmental quality condition in 2010 is the best, with an RSEI value of 0.7516. As can be seen from Figure 3, the regions with the greatest improvement in RSEI are distributed in the northwestern part of Sanming City, the northern part of Longyan City, the central Quanzhou City, Putian City, and western Fuzhou City, and the areas with the greatest deterioration are distributed in Xiamen City, northeastern Zhangzhou City, southern Quanzhou City, and southwestern Ningde City.

As can be seen from Table 3, from 2005 to 2020, the average value of RSEI of all cities in Fujian Province is improved, except for Xiamen City, which is decreased, indicating that the ecological environmental quality in Fujian Province has been better. The ecological and environmental health of Sanming City in the province has been maintained at a good level, and the average value of RSEI from 2005 to 2020 has been the highest; while the ecological and environmental health of Xiamen City is the worst, and the average value of RSEI from 2005 to 2020 is around 0.50. Fuzhou has improved from 2005 to 2020 with an RSEI mean value of about 0.06, and the RSEI value in the southeastern coastal region has continued to become larger, indicating that the highly centralized urbanization construction in the southeastern coastal region has a greater impact on ecology.

3.2 Spatial and temporal analysis of Fujian Province from 2005 to 2020 based on land use intensity

According to the construction of the land use intensity system in Section 2.2, this paper derives the land use change map (Figure 5-6) and land use intensity table (Table 4) for Fujian Province from 2005 to 2020, and this section mainly describes the spatial and temporal analysis of the land use situation in Fujian Province.

As can be seen from the figure, most of the land in Fujian Province is forest land, and from 2005 to 2020, the area occupied by forest land is continuously decreasing, but still accounts for a relatively high proportion. 15 years, there is a large increase in arable land and construction land, while forest land and grassland are correspondingly decreasing. As can be seen from Table 4, the land use emphasis in Fujian Province has been increasing again, with the highest land use intensity of 0.5398 in 2020; all cities in the province, except Putian City, have increased their land use intensity, with Sanming City increasing the most.

3.3 Coupling coordination degree analysis

According to the coupled coordination model in Section 2.3 to calculate the coordination of RSEI and land use intensity, this paper arrives at the coupled coordination degree from 2005 to 2020 in Fujian Province city, as shown in Table 5 and Figure 6.

From Table 5 and Figure 6, the coupling coordination degree of Fujian Province increases from 0.1 (severely dysfunctional) in 2005 to 0.550 (barely coordinated) in 2010, then increases again to 0.85 (well coordinated) in 2015, and finally adjusts downward to 0.829 (well coordinated) in 2020. Among the cities in the province, the overall trend of coupling coordination in Fuzhou, Sanming and Ningde is consistent, and is in the rising stage from 2005 to 2020; the overall trend of coupling coordination in Putian and Zhangzhou is consistent, and is in the rising stage from 2005 to 2015 and in the declining stage from 2015 to 2020; Xiamen, Quanzhou, Nanping and Longyan The overall trend of coupling coordination is consistent, being in an increasing phase from 2005 to 2010 and from 2015 to 2020, and in a decreasing phase from 2010 to 2015. in 2020, the coupling coordination is higher than 0.9 (high quality coordination) in Fuzhou and Ningde, and the lowest is 0.315 (light coordination) in Xiamen.

4 Discussion

4.1 Nature-based solutions put into practice

According to the study on the spatial and temporal distribution of ecological environment quality in Fujian Province from 2005 to 2020 in Section 3.1, it can be seen from (e) in Figure 3 that during this period, the degree of ecological environment quality in some areas of Fujian Province has a large difference, and the positive areas are significantly more than the negative areas, indicating that the overall ecological environment of the province tends to be good, with the northwestern area of Longyan City, the southwestern area of Fuzhou City, the central area of Quanzhou City and most areas of Putian City tending to have a difference of 0.5. In 2021, the Department of Ecological

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Restoration of Land Space of the Ministry of Natural Resources released the "Collection of Typical Cases of Ecological Restoration in China", and Changting County was selected as one of the 18 typical cases out of 127 cases. This case focuses on the diversity of ecosystems, the typicality of ecological problems, and the comprehensiveness of restoration means and methods, reflecting Fujian Province's attempts to restore and comprehensively manage the mountain, water, forest, field, lake, grass and sand system, and showing that Fujian Province has made practical exploration of nature-based solutions in the process of ecological restoration, and has been able to rely on nature-based economic solutions to provide basic support for the county's poverty alleviation efforts. The above shows that nature-based solutions can be implemented in China, and can help people understand the relationship between "man and nature" in a more systematic way.

4.2 Gradual increase in ecological carrying pressure

According to the discussion in Section 3.2, the overall land use intensity growth rate in Fujian Province from 2005 to 2020 is 26%, and among the cities, Sanming City has the highest growth rate of 160.91%, indicating that the ecological carrying pressure in the area has increased. The extent of land construction utilization in the southeastern coastal region of Fujian Province is significantly higher than that in the inland region of northwestern Fujian. At the same time, the increasing urbanization has led to a surge in urban population, during which the resident population in Xiamen increased from 2.73 million to 5.18 million, with a growth rate of 89.74%, 5.3 times the growth rate of the province's resident population, and nearly 47% of which are non-resident population in the city. The high rate of population growth has brought a huge demographic dividend to the city while at the same time, it has also put an excessive demand on the ecological carrying capacity. Xiamen city has been continuously upgrading its ecological civilization during this period, and it is obvious that there is an imbalance between the rate of construction and the population growth rate, which may be one of the reasons why the quality of the city's ecological environment in section 3.1 and the coupling synergy in section 3.3 are lower than those of other cities in the same province. With the call of the times to continuously build a strong socialist modernization country, the pace of urbanization and industrialization will continue to accelerate, and the pressure on ecological and environmental carrying capacity will also gradually increase.

4.3 "Social-Economic-Environmental" coupling of ecological civilization construction

According to the study on the coupling coordination degree of Fujian Province and local cities from 2005 to 2020 in section 3.3, it can be seen that the coupling coordination degree of Fujian Province increased from 0.1 to 0.829 during this period, and the coupling coordination degree level increased from "serious disorder" to "good coordination ", indicating that the province's ecological environment tends to be good, among which, the coupling coordination level of Fuzhou City and Ningde City reaches the quality coordination status. The reason for this is that Fujian Province started the construction of ecological civilization earlier, and in 2000, Xi Jinping, then governor of Fujian Province, put forward the strategic concept of building an ecological province, emphasizing that "any form of development and utilization should be carried out under the premise of ecological protection, so that the land of Bamin will be more mountainous and clear, and the economy and society will develop benignly in the perpetual use of resources "In 2002, Xi Jinping formally proposed the strategic goal of building an ecological province in the government work report of Fujian Province. In August 2002, approved by the former State Environmental Protection Administration, Fujian Province became one of the first pilot provinces in the country to build an ecological province. In April 2014, the State Council officially issued the "Opinions on Supporting Fujian Province in Further Implementing the Ecological Province Strategy and Accelerating the Construction of the Early Demonstration Zone of Ecological Civilization", making Fujian Province one of the first ecological provinces in China. In August 2016, the General Office of the CPC Central Committee and the General Office of the State Council issued the Opinions on the Establishment of a Unified and Standardized National Ecological Civilization Pilot Zone and the Implementation Plan of the National Ecological Civilization Pilot Zone (Fujian), which marked Fujian as the country's first ecological civilization pilot

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zone, which will lead and drive the construction of ecological civilization and institutional reform in the country. From the reform of collective forestry right system to the first ecological province, from the first provincial ecological civilization demonstration zone to the first national ecological civilization pilot zone, this series of ecological civilization construction results show that Fujian Province is beginning to bear fruit in the construction of ecological civilization, and also provides the "Fujian program" for the construction of ecological civilization in China.

5 Conclusion

In this paper, we analyzed the coupling and coordination degree of remote sensing ecological index and land use intensity data in Fujian Province, and obtained the coupling and coordination index system of land use and ecological environment quality in Fujian Province from 2005 to 2020 with a raster space of 500m×500m, and analyzed the spatial and temporal changes of ecosystem health in Fujian Province under the coupling effect of two systems: ecological environment quality and land use intensity. The main findings include The main conclusions include.

(a) The ecological environmental quality of Fujian province is in a stable and improving trend, with a province-wide good grade, and the average value of RSEI is 0.7048 (as of the end of 2020, the same below), and all cities in the province are in a good grade except Xiamen, which is in an average state; the average value of RSEI in the year 2020 is 6.40% higher in Fujian province compared with 2005; Ningde City has a growth of 16.71%, the most significant; Xiamen City decreases by 1.24%, the most obvious decrease; other cities increase in the range of 9.14% to 2.27%, respectively.

(b) Land use intensity in Fujian Province increased by 26.00% with an increase of 0.1114; among them, Sanming City increased most significantly with 160.91%; Putian City decreased most significantly with 3.52%; other cities increased within the range of 10.88% to 101.82% respectively.

(c) The coupling coordination between ecological environment quality and land use intensity in Fujian province is generally in a good state of coordination, with a coupling value of 0.8290; among the cities in the province, Fuzhou and Ningde are in a state of high quality coordination, and Xiamen is in a state of mild disorder; in 2020, the coupling value in Fujian province increases by 0.729 compared with 2005, and among the cities in the province, Ningde has the most significant growth, with a value of 0.8637; Xiamen has the most significant growth. The value is 0.8637; Xiamen City is the most obvious decrease, with a decrease value of 0.131.

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