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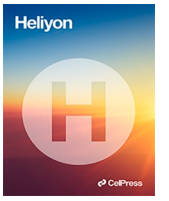

Assessment and analysis of the balance between economic development and ecological environment protection and its implementation strategy derived from spatial planning—Take three heterogeneous and representative provinces in China as an example

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ABSTRACT

Balancing ecological environment protection (EEP) and economic development (ED) (balance for short) is a difficult problem that must be solved in the development of modern society, particularly important for realizing UN Sustainable Development Goals. How to assess the regional balance situation and reveal the spatial and temporal heterogeneous characteristics of the balance (especially for the vast China) and its influencing factors are the primary scientific problems and realistic needs. Taking Zhejiang, Hunan and Gansu Provinces in the eastern, central and western region of China as a regional representative, an index system characterizing EEP and ED were established, which were processed by extreme difference method and entropy weight method. The coupling characteristics, stress factors and coordination type from 2010 to 2019 in the 3 provinces were assessed and analyzed by means of the coupling coordination model and the grey correlation degree model. Balance is the mission and responsibility of the spatial planning system for spatial planning is of the source, whole-region and comprehensiveness of public strategy, therefore, the balance strategies and its integration approaches are constructed in the 3 provincial spatial planning based on the assessment and analysis of balance characteristics. Research results show that: (1) the 3 provinces' coupling coordination degree is rising year by year, coordination type is more and more better indicating that the balance of EEP and ED is getting better and better, but coordination type differentiates at one level between 3 provinces at the east, central, western region of China, Zhejiang province is from nearby imbalance to primary coordination, Hunan Province is from nearby imbalance to narrow coordination, and Gansu Province is from medium imbalance to nearby imbalance. (2) The ED have same strong stress on EEP in the 3 provinces, and the constraints of EEP on ED are different, the current balance characteristics of Zhejiang, Hunan and Gansu province are the types of ecological environment pressure constraints primary coordination, ecological environment pressure constraints narrow coordination, and ecological environment condition constraints nearby imbalance. (3) The coordination types are the co-environmental pressure constraints primary coordination (Zhejiang Province), eco-environmental pressure constraints narrow coordination (Hunan Province) and eco-

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environmental condition constraints nearby imbalance (Gansu Province), and corresponding balanced planning strategy system are to promote ecological modernization, implement ecological industrialization and adhere to the ecological fundamentalization.

1. Introduction

Balancing the ecological environment protection (EEP) and economic development (EEP) (balance for short), i.e the EEP and ED are compatible so as to achieve a win-win situation. Balance is difficult and particularly important for realizing UN Sustainable Development Goals. Therefore, how to assess the regional balance situation and reveal the spatial and temporal heterogeneous characteristics of the balance (especially for the vast China) and its influencing factors are the primary scientific problems and realistic needs.

How to promote balance? Balance is a system engineering and need to implement strategies not only from the aspects of vigorously promoting green circular low-carbon development, making industries ecotypically, and promoting high-quality economic development, but also from the aspects of pollution prevention and control, EEP, resource conservation recycling and paid use system and eco-compensation system, and furthermore, a comprehensive and source strategy. Planning is the source of public strategy. Giving full play to the balanced role of territorial spatial planning is the strategic deployment of the Chinese Government in recent years [1–3]. The territorial spatial planning is an overall planning for the protection, development, utilization and restoration of territorial space, a guide for territorial space development, a blueprint for sustainable development, and a basic for all kinds of 56 development, protection and construction activities. Therefore, balance is the mission of the territorial spatial planning system which contain four basic elements of strategic guidance, bottom-line control, sustainable development and all-round coordination [4].

The development of foreign territorial spatial planning shows that more attention is paid to ecological environment, quality improvement and resilient development, so as to achieve harmony and sustainable development between human and nature. Spatial planning was defined as a method of influencing the future activity space distribution used primarily by the public sector in *Synopsis of the European Spatial Planning System and Policy*. It aims to create a more rational territorial organization of the relationships between land use and function, balance the two needs of EEP and ED, and achieve the goal of coordinated social and economic development. Strategic environmental impact assessment is incorporated into the system of spatial planning in European countries such as Germany and the United Kingdom [5]. In Germany, all infrastructure construction should be evaluated for environmental compatibility, and impacts on animals, plants, soil and landscape should be specified [6]. In the latest seventh territorial spatial planning of Japan, improving disaster resistance, building beautiful land, energy conservation and environmental protection are included in the basic strategies of territorial space planning [7].In Netherlands, the evaluation of noise hazard, air quality, external safety, soil, water, natural protection area, archaeological value and so on must be completed firstly, and relevant technical details should be detailed in planning and supplementary documents afterwards [8].The fifth spatial planning proposed to meet the needs of space as much as possible, ensure the coordination and unity of space quality, and give consideration to the balance between ED and EEP. In the process of territorial spatial planning in the European Union [9], Spain [10], the Netherlands [11], Finland [12], Ireland [13]and other countries, sustainable development is listed as an important goal and guidance [14]. The role, problem and the necessity for cooperation of institutional control and local autonomy in land use planning in balancing economic development with environmental protection were studied in USA [15]. Research on territorial spatial planning in China mainly focuses on learning advanced foreign experience and drawing lessons from developed countries [16,17], pilot exploration of preparation of planning [18–22] and discussion on planning content and technical methods, for example, resource and environmental carrying capacity and territorial space suitability assessment methods [23,24], the division of “Three regions and three Lines” and the application of big data and other information methods [25–28], or research on the formulation of territorial spatial planning for cities, counties and provinces [29–32].However, the appeal of balance is put forward in the theoretical research of territorial spatial planning [4], which emphasize that territorial spatial planning has entered a new era of ecological civilization, and should embody the requirements of ecological civilization construction. The future three demand trends are comprehensive humanization of subject, comprehensive development ecotypically of object and regional network of group [33,34]. People oriented territorial space planning requires the integration of nature and human, production, life and ecology to promote green development in the new era [35].Spatial planning is undergoing a transformation from material planning in the incremental era to quality planning in the stock era. In particular, under the background of strong resource constraints, it is necessary to find an innovative path for the country to enter the high-quality development in the stock era and achieve maximum efficiency and equity with the minimum consumption of natural resources [36,37], taking Xiuwu County of Henan Province as an example, discussed the formulation thinking of urban and rural planning based on the balance concept of ecological protection and economic construction from the aspects of regional ecological pattern analysis, formulation of urban space access mechanism, industrial development and spatial layout planning, etc.

Overall, the balance strategy was integrated into territorial spatial planning in developed countries, however in China, was mostly in the ideas and theoretical development. In the past, eco-environmental protection plans or social and economic development plans tended to focus on one side and lose the other, making it difficult to achieve such a balance. The territorial spatial planning can only fulfill the balancing responsibility. Therefore, how to systematically construct balance strategy from a new perspective of territorial spatial planning, and how to integrate the balance strategy into the current top-level design of territorial spatial planning are scientific and practical problems to be solved. However, China’s territorial spatial plan is being drawn up, China has a vast territory, and the economy and eco-environment differ greatly between the eastern, central and western regions in China. Taking the Zhejiang, Hunan

and Gansu provinces in the eastern, central and western China as a regional representative, this paper established an index system characterizing EEP and ED, which were processed by extreme difference method and entropy weight method, analyzed the balance characteristics and stress factors from 2010 to 2019 by means of the coupling coordination model and the grey correlation degree model, and constructed the balance strategy and integration approaches in provincial territorial spatial planning (Fig. 1). So, the research purposes are to assess the regional balance situation, reveal the spatial and temporal heterogeneous characteristics of the balance in China and its influencing factors, and construct the balance strategy and integration approaches. The research novelty is to reveal the spatial and temporal heterogeneous characteristics and construct systematically balance strategy from a new perspective of territorial spatial planning which has the characteristics of source, whole region and comprehensiveness.

2. Methodology

2.1. Study area

This paper research the construction of balance strategy with a case study of provincial territorial spatial planning. Considering the great regional differences in China, Zhejiang, Hunan and Gansu are selected as representatives in the eastern, central and western China (Fig. 2, Table 1).

Zhejiang province is located in the eastern coast of China and the south of the Yangtze River Delta, between 27°02′~31°11′ N and 118°01′~123°10′ E. It has jurisdiction over 2 sub-provincial cities and 9 prefecture-level cities, covering a land area of 105.5 thousand km^2. It is a key province of the Yangtze River Economic Belt Strategy and an important part of the Yangtze River Delta urban agglomeration. It is located in the frontier area of reform and opening up, an important gateway of the domestic and international double-circulation, and an important hub of "the Belt and Road" Strategy. Both land and sea resources.

Hunan province is between 24°38′~30°08′ N and 108°47′~114°15′ E. It has the hub position of connecting east and west, connecting north and south. It has jurisdiction over 14 cities (states) with a total area of 211.8 thousand km^2. It is the famous "hometown of nonferrous metal" and "hometown of fish and rice". It has superior resource conditions and ecological environment background.

Gansu Province is between 32°11′~42°57′ N and 92°13′~108°46′ E. It has jurisdiction over 14 cities (states) with a total area of 425.8 thousand km^2. It is located in the intersection of three plateaus and three natural regions, with high mountains, basins, plains, deserts and gobi, with vulnerable ecological environment. The ancient Silk Road and the new Asia-Europe continental bridge traversed the territory.

There are huge differences in social economy and eco-environment between the 3 Province, for example, in 2019, GDP was ranked among 31 provinces and autonomous regions (excluding Hong Kong, Macao and Taiwan), with Zhejiang ranking fourth, Hunan ranking ninth and Gansu ranking 27th, and GDP per capita, with Zhejiang ranking fourth, Hunan ranking 14th and Gansu ranking 31st. Waste water emission per capita, Zhejiang is 2.2 times to Hunan, 3.7 times to Gansu.

In short, the 3 provinces have different geographical conditions, unique natural conditions and natural resources, and significant differences in social economy and environment, which are typical and representative in China. Therefore, the 3 provinces are selected as case studies.

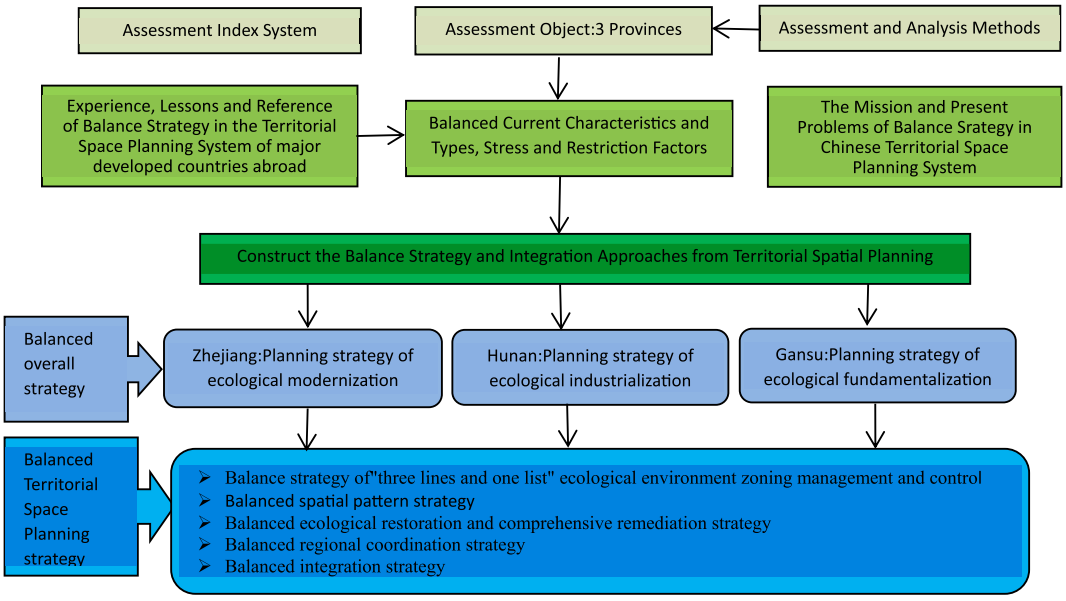

Fig. 1. Research roadmap.

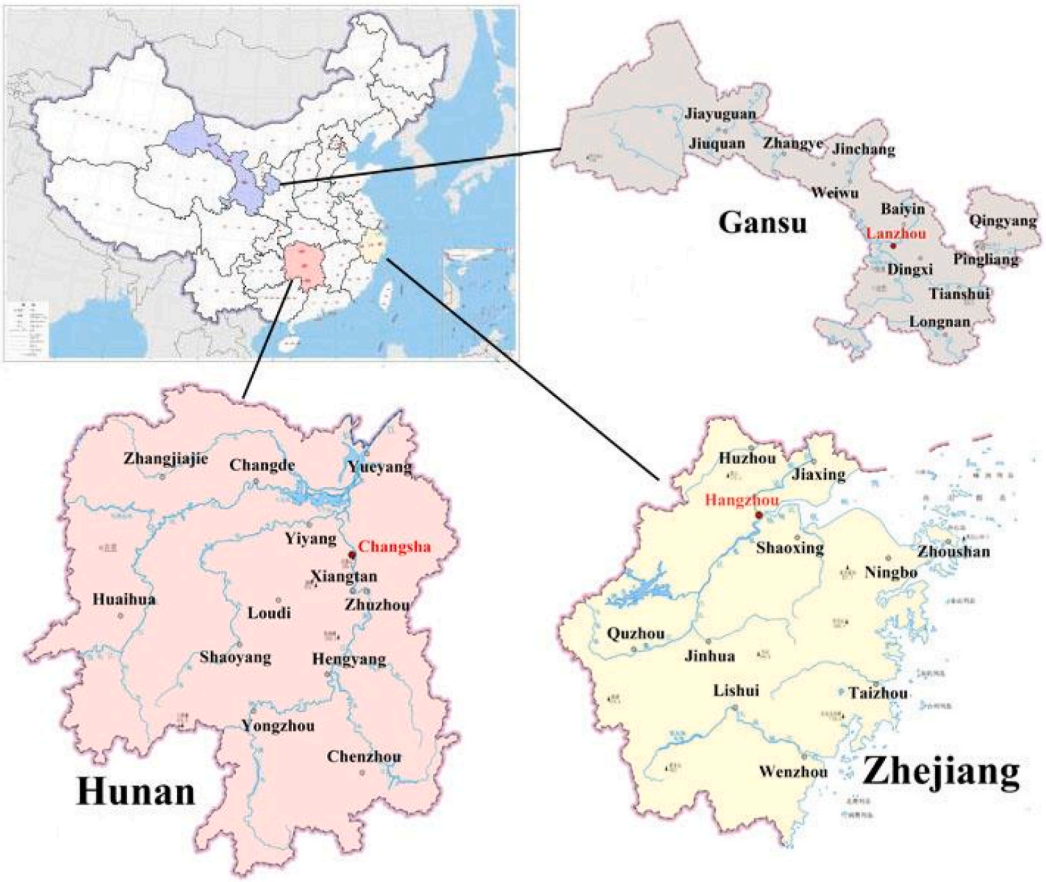

Fig. 2. Location of Zhejiang, Hunan and Gansu Provinces in China.

2.2. Data sources and research methods

The data of the study period from 2010 to 2019 mainly come from the following four aspects: ①China and Zhejiang, Hunan, Gansu Provinces Statistical Yearbook and Bulletin. ②Report on the work of the three provincial governments. ③EPSDATA network database: China Regional Economic Development Yearbook, China Urban and Rural Construction Statistical Yearbook, China Energy Statistical Yearbook, China Resources and Environment Statistical Yearbook. ④ Website of 3 provincial government departments: website of water conservancy department, natural resources department and environmental protection department.

According to the principles of scientific, operable, systematic and regional, the index system covering EEP and ED should be constructed, where 20 representative indexes and 10 indexes respectively for EEP and ED were selected (Table 2). Economic scale and structure are the basic representations of economic development, have direct influence on economic benefit. Eco-environment condition are the foundation and resource input of economic development, affect economic scale and structure; economic development cause pressure and damage to eco-environment, and it require economic input to improve the eco-environment, will inevitably affect economic benefit. Therefore, the selected indicators can not only reflect the characteristics of each subsystem, but also reflect the connection mechanism and logical relationship between the two subsystems. The relevant index values from 2010 to 2019 were collected, and the positive and negative indicators were standardized by extreme difference method, and the weight was determined by entropy method [38] (Table 2).

The formula for computing the comprehensive evaluation indexes of ED and EEP in the 3 provinces from 2010 to 2019 by the weighted arithmetic average method are shown in Equation (1) and Equation (2):

$$f(x) = \sum_i^n a_i x_i \tag{1}$$

where $f(x)$ is the comprehensive evaluation index of ED, n is the number of ED indicators, a_i is the weight of indicators.

$$g(y) = \sum_j^m b_j y_j \tag{2}$$

where $g(y)$ is the comprehensive evaluation index of EEP, m is the number of EEP indicators, b_j is the weight of indicators.

Table 1
Some current situation of eco-environment and economy in Zhejiang, Hunan and Gansu Provinces.

Year	GDP per capita (Yuan/person)			Urbanization level (%)			Water resource ownership per capita (m^3/person)			Waste water emission (10 thousand tons)			Exhaust emission (100 million m^3)		
	Zhe jiang	Hunan	Gansu	Zhe jiang	Hunan	Gansu	Zhe jiang	Hunan	Gansu	Zhe jiang	Hunan	Gansu	Zhe jiang	Hunan	Gansu
2010	57,709	22,537	15,405	60.32	44.65	36.17	2609	2939	988	394,828	268,110	51,241	20,434	14,673	6252
2011	66,624	27,409	18,785	62.30	45.10	37.15	1366	1712	1061	420,134	278,811	59,232	24,790	16,778	12,891
2012	71,640	30,648	20,922	63.20	46.65	38.75	2645	3006	1167	420,961	304,214	62,813	23,967	15,887	13,899
2013	77,347	34,191	23,292	64.00	47.96	40.13	1697	2374	1174	419,120	307,227	64,969	24,564	17,276	12,676
2014	82,675	37,221	25,160	64.87	49.28	41.68	2057	2680	891	418,262	309,960	65,973	26,958	16,050	12,290
2015	88,002	39,477	25,222	65.80	50.89	43.19	2548	2839	765	433,822	314,107	67,072	26,841	15,320	13,293
2016	96,224	42,204	26,468	67.00	52.75	44.69	2378	3229	803	430,857	298,756	66,325	22,185	15,685	10,639
2017	105,702	46,466	27,942	68.00	54.62	46.39	1806	2811	1069	453,935	300,563	64,514	31,310	14,532	9007
2018	116,009	49,717	30,729	68.90	56.02	47.69	1733	1952	1346	463,895	324,662	70,049	28,498	14,678	11,938
2019	123,741	54,310	32,931	70.00	57.22	48.49	2622	2866	1231	476,707	312,612	67,281	32,834	13,674	10,472

Table 2
Index system and its weight value for evaluation of EEP and ED.

Target layer	Middle layer	Weight	Index layer[a]	Unit	Weight
ED	Economic scale	0.426	GDP per capita X_1	Yuan/person	0.105
			Investment in fixed assets per capita X_2	Yuan/person	0.092
			Total retail sales per capita X_3	Yuan/person	0.108
			Total net exports X_4	Yuan/person	0.121
	Economic structure	0.375	Proportion of secondary industry X_5	%	0.144
			Proportion of tertiary industry X_6	%	0.166
			Proportion of primary industry X_7	%	0.065
	Economic benefits	0.199	Social labor productivity X_8	Yuan/person	0.076
			Urban per capita disposable income X_9	Yuan/person	0.081
			Urbanization level X_{10}	%	0.042
EEP	Eco-environmental condition	0.392	Forest coverage rate Y_1	%	0.159
			Cultivated area per capita Y_2	Ha/person	0.135
			Water resource ownership per capita Y_3	m^3/person	0.107
			Park green area per capita Y_4	m^2/person	0.091
	Eco- environmental governance	0.334	Urban sewage treatment rate Y_5	%	0.032
			Harmless treatment rate of household garbage Y_6	%	0.058
			Proportion of investment in environmental Governance in GDP Y_7	%	0.143
	Eco- environmental pressure	0.274	Solid waste emission Y_8	10 thousand tons	0.130
			Exhaust emission Y_9	100 million m^3	0.106
			Waste water emission Y_{10}	10 thousand tons	0.038

[a] Y8, Y9 and Y10 are negative indicators, the rest are positive indicators.

In Equation (1), x_i is the standardized value of each ED indicator. The standardized value was calculated by extreme difference method.

When it is the positive indicator, the formula is shown in Equation (3):

$$x_i = \left(X_i - X_{\min}\right) / \left(X_{\max} - X_{\min}\right) \tag{3}$$

where X_i, $X_{\max}$, $X_{\min}$ are a ED indicator value, max value and min value respectively.

When it is the negative indicator, the formula is shown in Equation (4)

$$x_i = \left(X_{\max} - X_i\right) / \left(X_{\max} - X_{\min}\right) \tag{4}$$

In Equation (2), y_j is the standardized value of each EEP indicator calculated by extreme difference method same as Equations (3) and (4).

The coupling coordination model was used to calculate the coupling coordination between EEP and ED in 3 provinces from 2010 to 2019 to reflect their balanced status. The formula of coupling degree between EEP and ED is shown in Equation (5):

$$C = \left(\left(f(x) \times g(y) \right) / \left(f(x) + g(y) \right)^{\frac{1}{2}} \right. \tag{5}$$

where C is the coupling degree.$0 \leq C \leq 1$, C can be divided into six types: $C = 0$, indicating no coupling degree and no correlation; $0 < C \leq 0.3$, lower level period; $0.3 < C \leq 0.5$, rivalry phase; $0.5 < C \leq 0.8$, running-in stage; $0.8 < C \leq 1$, high level coupling phase. The formula of coupling coordination degree between EEP and ED is shown in Equation (6) and Equation (7):

$$D = (C * T)^{\frac{1}{2}} \tag{6}$$

$$T = \alpha f(x) + \beta g(y) \tag{7}$$

Table 3
Coordinated classification criteria for EEP and ED.

Coupling coordination	Coordinated development zone	Coordinated development type
0.00–0.10	Disorders of recession	Extreme disorder recession type
0.11–0.20		Severe disorder recession type
0.21–0.30		Moderate disorder recession type
0.31–0.40	transition to reconcile	Mild disorder recession type
0.41–0.50		Endangered disorder recession type
0.51–0.60		Barely coordinated development type
0.61–0.70	Low coordination	Primary coordinated development type
0.71–0.80		Intermediate coordinated development type
0.81–0.90	High coordination	Well coordinated development type
0.91–1.00		Quality coordinated development type

where D is the coupling coordination degree, and T is the comprehensive evaluation index, α and β are the weights, assignment $\alpha = \beta = 0.5$. D takes the value from 0 to 1; The closer the D value is to 1, the higher the level and the better the coordination; The closer the D value is to 0, the lower the level and the more incongruous it is (Table 3).

The grey correlation degree model [39] was used to calculate the correlation degree between EEP and ED in the 3 provinces, determine the strong correlation index, and analyze its influencing factors.

$X_0 = (x_0(1), x_0(2), \cdots, x_0(n))$ is the reference sequence, refer to ED indicator sequence here, $X_i = (x_i(1), x_0(2), \cdots, x_i(n))$ is comparison sequence, refer to EEP indicator sequence here, the formula of the correlation coefficient of $x_0(k)$ and $x_i(k)$ is shown in Equation (8):

$$\gamma(x_0(k), x_i(k)) = \frac{\min\limits_i \min\limits_k |x_0(k) - x_i(k)| + \rho \max\limits_i \max\limits_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \rho \max\limits_i \max\limits_k |x_0(k) - x_i(k)|} \times \frac{1}{m} \tag{8}$$

where ρ is resolution coefficient between 0 and 1, $\rho = 0.5$ commonly.

Correlation degree was calculated as Equation (9):

$$r_i = \frac{1}{n} \sum_{k=1}^{n} r_i(k) \tag{9}$$

According to the coupling and coordination types and balance characteristics of EEP and ED in the 3 provinces, combined with the requirements of *Provincial Territorial Spatial Planning Guidelines* and *The 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Outline of Vision for 2035*, the provincial balance strategy and its integration strategy were put forward.

3. Results

3.1. Assessment and analysis of coupling coordination: the balance spatiotemporal evolution

Coupling coordination results of EEP and ED in Zhejiang, Hunan and Gansu provinces from 2010 to 2019 is showed in Fig. 3.

3.1.1. The coupling coordination degree of the 3 provinces increased year by year in temporal change

The coupling coordination degree are all with an increase of 0.12 from 2010 to 2019. The coordinated development types ranged from endangered disorder to primary coordination (Zhejiang), endangered disorder to barely coordination (Hunan), and moderate disorder to endangered disorder (Gansu), indicating that the balance was getting better and better.

3.1.2. There were obvious differences among the 3 provinces in spatial distribution

The highest in Zhejiang, the second in Hunan, and the lowest in Gansu. The coordination types differ by one level, for example, the coordinated development type of Gansu province was endangered disorder in 2019, which was the same as the initial type of Hunan Province in 2010. Hunan province was barely coordination in 2019, which was the same as Zhejiang Province in 2013, and Zhejiang province has reached primary coordination in 2019. On the one hand, it reflects the influence of provincial economic development transformation and high-quality economic development, and show the overall trend from neglecting to paying attention to EEP in the process of ED, the two systems of EEP and ED are gradually coupled and coordinated. However, on the whole, the current coupling

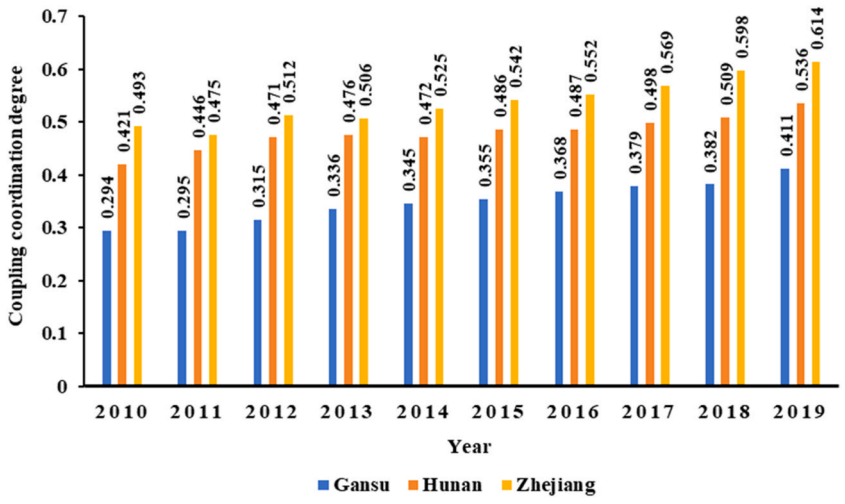

Fig. 3. Coupling coordination trend of EEP and ED from 2010 to 2019 in Zhejiang, Hunan and Gansu Provinces.

Table 4
Grey correlation degree of EEP and ED in Zhejiang Province.

Indicators			ED										
			Economic scale (0.7506)				Economic structure (0.7453)			Economic benefits (0.7464)			Average
			X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	
EEP	Eco-environmental condition (0.7463)	Y1	0.7401	0.7435	0.7443	0.7254	0.7509	0.7554	0.7432	0.7201	0.7443	0.7492	0.7436
		Y2	0.7647	0.7467	0.7558	0.7311	0.7601	0.7531	0.7456	0.7556	0.7410	0.7409	0.7515
		Y3	0.7511	0.7444	0.7466	0.7205	0.7531	0.7589	0.7387	0.7412	0.7467	0.7401	0.7461
		Y4	0.7667	0.7439	0.7467	0.7267	0.7457	0.7216	0.7467	0.7421	0.7412	0.7402	0.7442
	Eco-environmental governance (0.7429)	Y5	0.7556	0.7467	0.7465	0.7265	0.7481	0.7276	0.7344	0.7451	0.7445	0.7456	0.7441
		Y6	0.7531	0.7219	0.7488	0.7288	0.7421	0.7243	0.7433	0.7215	0.7232	0.7496	0.7371
		Y7	0.7521	0.7467	0.7677	0.7577	0.7261	0.7478	0.7421	0.7445	0.7471	0.7541	0.7476
	Eco-environmental pressure (0.7544)	Y8	0.7656	0.7397	0.7399	0.7199	0.7498	0.7437	0.7451	0.7650	0.7434	0.7567	0.7494
		Y9	0.7763	0.7697	0.7642	0.7221	0.7478	0.7607	0.7456	0.7567	0.7622	0.7699	0.7621
		Y10	0.7611	0.7639	0.7447	0.7247	0.7465	0.7656	0.7467	0.7478	0.7465	0.7645	0.7517
	Average		0.7586	0.7467	0.7496	0.7283	0.7470	0.7459	0.7431	0.7440	0.7440	0.7511	

coordination degree is not high, and the coupling coordinated development is not optimized, so it is necessary to further balance the relationship between EEP and ED. On the other hand, it reflects the differences of resource environment endowment, location condition and economic development level in the 3 provinces. Zhejiang province is located in the strategic area of priority development in eastern China, with the highest level of economic development, so the coupling coordination level is the highest. Hunan province, supported by the Rise of Central China Strategy, has been continuously achieving high-quality development, and the coupling coordination degree is also rising. Gansu province has the lowest coupling coordination degree. However, with the in-depth development of Western Development Strategy, its coupling coordination degree is also increasing year by year and gradually narrowing the gap with the two provinces.

3.2. Analysis of grey correlation: main aspects and factors affecting the balance

The grey correlation degree of EEP system and ED system in Zhejiang (Table 4), Hunan and Gansu provinces (Appendix Tables 1 and 2) from 2010 to 2019 was calculated, each value represents the grey correlation degree of the 10-year time series of the two related indicators from 2010 to 2019.

3.2.1. The main aspects of stress and restriction of EEP system and ED system

In Zhejiang Province (Table 4), the correlation degree between economic scale, economic structure, economic benefits of the ED system and EEP system is 0.7506, 0.7453 and 0.7464 respectively. The results show that the degree of stress of ED on EEP system is in the decrease order of economic scale, economic benefit and economic structure, the economic scale is the main aspect of stress. The correlation degree between eco-environmental conditions, eco-environmental governance, eco-environmental pressure of the EEP system and ED system is 0.7463, 0.7429 and 0.7544 respectively. It shows that the degree of restriction of EEP system to ED system is in the decrease order of eco-environmental pressure, eco-environmental conditions, eco-environmental governance, the eco-environmental pressure is the main aspect of restriction.

In Hunan Province (Appendix Table 1), the degree of stress of economic development system on eco-environmental protection system is in the decrease order of economic scale, economic benefit and economic structure, economic scale is the main aspect of stress. The degree of restriction of eco-environmental protection system to economic development system is in the decrease order of eco-environmental pressure, eco-environmental conditions, eco-environmental governance, the eco-environmental pressure is the main aspect of restriction.

In Gansu Province (Appendix Table 2), the degree of stress of ED system on EEP system is in the decrease order of economic scale, economic structure and economic benefit, the economic scale is the main aspect of stress. The degree of restriction of EEP system on economic system is in the decrease order of eco-environmental condition, eco-environmental pressure and eco-environmental governance, the eco-environmental condition is the main aspect of restriction.

In short, the economic scale of the 3 provinces ranks the first in terms of the stress degree of the ED system on the EEP system, however the second are economic benefits in Zhejiang and Hunan, economic structure in Gansu. It is pointed out that how to realize the unification between economic scale and benefit in Zhejiang and Hunan is a problem to be solved for a long time in the future, and Gansu needs to improve economic benefit and realize scale expansion by vigorously adjusting economic structure. The restriction degree of EEP system on ED system ranks first being eco-environmental pressure in Zhejiang and Hunan, while eco-environmental conditions in Gansu. It shows that Gansu in the western eco-vulnerable zone should take improving the ecological environment as the first task.

3.2.2. Strong correlation index between EEP system and ED system

In Zhejiang, the strong grey correlation index between ED system and EEP system (the former) is X_1 (GDP per capita) 0.7586, X_{10} (urbanization level) 0.7511. The strong grey correlation index between EEP system and ED system (the latter) is: Y_9 (exhaust emission) 0.7621, Y_{10} (waste water emission) 0.7517, Y_2 (cultivated area per capita) 0.7515. In Hunan, the strong grey correlation index of the former is X_1 (GDP per capita) 0.7412, X_7 (proportion of primary industry) 0.7328, X_{10} (urbanization level) 0.7327. The latter is Y_{10} (waste water discharge) 0.7375, Y_2 (cultivated area per capita) 0.7343, Y_8 (solid waste emission) 0.7306. In Gansu, the strong grey correlation index of the former is X_1 (GDP per capita) 0.7154, X_5 (proportion of secondary industry) 0.7079. The latter is Y_3 (water resource ownership per capita) 0.7141, Y_1 (forest coverage rate) 0.7090, and Y_8 (solid waste emission) 0.7014. The differences of the strong correlation indicators in the 3 provinces are obvious, thus the strong correlation indicators become the factors of stress and constraint.

3.3. Analysis of balance characteristics between EEP and ED

From 2010 to 2019, the coupling coordination degree of the 3 provinces all shows an increasing trend year by year, and the coordination type also gradually improved. But the degree of coordination shows a trend of decreasing step by step between Zhejiang, Hunan and Gansu Province. The grey correlation degree between EEP system and three subsystems of the ED system also shows a decreasing trend. For example, the correlation degree ranges of the 3 sub-systems of EEP and economic system are respectively 0.7429~0.7544, 0.7263~0.7324 and 0.6900~0.7039, while the correlation degree ranges of the three sub-systems of ED and EEP system are respectively 0.7453~0.7506, 0.7277~0.7305 and 0.6929~0.7130 in Zhejiang, Hunan and Gansu Province. This shows that the degree of integration and balance between EEP and ED in eastern, central and western China decreases respectively. In the aspect of EEP restricting ED, Zhejiang and Hunan are restricted by ecological environment pressure, Gansu is restricted by ecological

environment conditions. In terms of the stress of economic development on eco-environmental protection, the 3 provinces all show the stress of economic scale. In *the Guidelines for the Compilation of Provincial Territorial Spatial Planning* (for Trial Implementation), "giving priority to ecology and green development" is the primary planning principle. Therefore, when analyzing the balanced characteristics of EEP and ED, the restriction role of EEP on ED should be first considered. The balanced types of EEP and ED in each province are named according to the different restriction characteristics.

3.3.1. Zhejiang: the primary coordinated type restricted by ecological environment pressure

The restriction factors of EEP on ED are mainly the exhaust emission, waste water emission and cultivated land area per capita, namely the restriction of environmental pollution. The stress of ED on EEP is mainly manifested in GDP per capita and urbanization level. The pressure of EEP is the main aspect that restricts economic development. Combined with the coordinated development type, Zhejiang Province is the primary coordinated type restricted by ecological environment pressure.

3.3.2. Hunan: the bare coordinated type restricted by ecological environment pressure

The restriction factors of EEP on ED are mainly waste water emission, cultivated land area per capita, solid waste emission, namely the restriction of environmental pollution. The stress of ED on EEP is mainly manifested in GDP per capita, proportion of primary industry and urbanization level. The pressure of EEP is the main aspect that restricts economic development. Combined with the coordinated development type, Hunan Province is the bare coordinated development type restricted by ecological environment pressure.

3.3.3. Gansu: the endangered disorder type restricted by eco-environmental conditions

The restriction factors of EEP on ED are mainly the water resource ownership per capita, forest coverage rate and solid waste emission, namely the restriction of resource conditions. The stress of ED on EEP is mainly reflected in GDP per capita and proportion of secondary industry. The ecological environment condition is the main aspect that restricts economic development. Combined with coordinated development type, Gansu Province is the endangered disorder type restricted by ecological environment condition.

4. Discussions

4.1. Construction of territorial spatial planning strategy of balancing EEP and ED

Strategy generally refers to a set of plans, guidelines of action and methods of struggle that can achieve goals, as well as the principles and means adopted to achieve strategic tasks. The balance strategy can be understood as adding a purpose-oriented strategy of balancing EEP and ED into territorial space planning, so as to achieve a balanced status in the implementation of territorial spatial planning. Following the principle of "ecological priority and green development" and taking into full consideration the balanced characteristics of ED and EEP in the 3 provinces, the balanced strategies of Zhejiang, Hunan and Gansu provinces are summarized as follows.

4.1.1. Zhejiang: planning strategy of ecological modernization

Ecological modernization theory is a comprehensive environmental theory and practice that aims at solving environmental problems in industrialized society of western developed countries, coordinating ecology and development, taking technology as the foundation and ecological innovation as the guidance. It shows people a realistic path to realize the sustainable development of economic benefits and eco-environmental benefits. Ecological modernization is the modernization that realizes the balance between EEP and ED.

Zhejiang Province has the foundation to carry out ecological modernization planning strategy. First, it is in an advantageous location located at the east coast of China, the intersection of the vertical axis of the coastal channel and the horizontal axis of the Yangtze River channel in the national urbanization strategy pattern of "two horizontal and three vertical". It is the key province of the Yangtze River Economic Belt Strategy, the part of the Yangtze River Delta Urban Agglomeration, the frontier area of reform and opening up, an important gateway of domestic and international double-circulation, and an important hub of the "The Belt and Road" Strategy. Second, it is the province with the highest coupling coordination degree and the best coordinated development type. Third, the economy is developed and the industry is advanced. In 2019, the GDP per capita has exceeded 100,000 yuan. The added value and growth rate of industry and service industry in Zhejiang Province show that digital economy (Year-on-year growth 16.8%, firstly) and high-tech industry (15.6%, secondly) (Appendix Table 3) as well as high-end service industry such as science and technology and information (22.7%, firstly in service industry sub-industries) have the highest growth rate and good development prospects (Appendix Table 4).

Zhejiang Province should focus on the goal of "striving to build an important window to fully display the superiority of socialism with Chinese characteristics in the new era" and "striving to be a pioneer province of social modernization", faithfully practicing the "Eight-eight Strategy" (Appendix Table 5), and should fully integrate into the Yangtze River Delta high-quality integrated development, accelerate the formation of a territorial spatial pattern in which human beings and nature coexist harmoniously, accelerate the construction of a "multi-planning united" spatial governance system and a leading province with modern governance capacity, beautiful china model province, provincial high-quality integration model province, and plan a new pattern of overall, intensive, harmonious, efficient and beautiful territory development and protection to achieve a high-level balance and common prosperity in the province. The cultivated land area per capita is the smallest among the 3 provinces. Zhejiang Province should strictly implement

the task of protecting cultivated land and permanent basic farmland, promote the whole area land renovation, strictly control the use of cultivated land, curb the non-agricultural use of cultivated land and prevent the non-grain use by means of satellite remote sensing and digital governance platform, real-time dynamic monitoring, strict law enforcement and supervision. The "Farmland Chief System" is fully implemented. The specific strategy system is shown in Appendix Table 5.

4.1.2. Hunan: planning strategy of ecological industrialization

Ecological industrialization is to enhance the stability of natural ecosystem, improve the supply of high-quality ecological products, enhance the ability to realize the value of ecological resources, so as to realize the unity of ecological benefits, economic benefits and social benefits.

Hunan province is surrounded by mountains on three sides and opens to the north in the shape of a horseshoe. More than two-thirds of the area is mountainous, with forest coverage rate 60%. Therefore, the eco-environmental background is excellent and the mineral resources are rich. The development and utilization of mineral resources produce serious waste water, exhaust gas and solid waste pollution, so the eco-environmental pressure (waste water emission, solid waste emission) has a strong correlation with economic development, which greatly restricts economic development. Hunan Province located in the central region with relatively developed economy and better eco-environmental background conditions. In order to realize the Rise of Central China through ED and EEP, we must transform to ecological industrialization in territorial space planning, take the road of green rising and the road of new urbanization, so as to realize the transformation from "clear waters and green mountains" to "mountains of gold and silver". We will give full play the advantages of ecological resources, coordinate ecological management of Dongting Lake and Xiang River, Zi River, Yuan River, and Li River basins, speed up ecological restoration in areas where mineral resources are concentrated, and promote ecological restoration and management in ecologically fragile areas, especially in areas of tailing mines and heavy metal pollution, so as to form a green, safe, livable, high-quality, intensive and efficient, open, coordinated and beautiful Hunan (Appendix Table 5).

4.1.3. Gansu: planning strategy of ecological fundamentalization

Ecological fundamentalization, namely, EEP is the basic premise of territorial space planning. In western China, the economy is underdeveloped, ecological environment background conditions is not excellent, and EEP is not good. In the process of balancing EEP with ED, EEP should be placed on a fundamental position and preferred. Gansu Province is located at the intersection of the Loess Plateau, Qinghai-Tibet Plateau and Inner Mongolia Plateau, the arid northwest, Qinghai-Tibet Alpine region and eastern monsoon region. The topography is complex, with mountains, basins, plains, deserts and gobi, of which desert gobi accounts for 14.99% of the total area of the province. It is in the national northern sand prevent construction belt, a part of the Qinghai-Tibet Plateau-Sichuan-Yunnan ecological barrier, and vulnerable in ecological environment, so it needs to complete important ecological tasks such as wind prevention and sand fixation, water and soil conservation. The grey correlation between economic development scale (GDP per capita), economic structure (proportion of secondary industry) and EEP is strong, which brings great stress to EEP. Eco-environmental conditions (water resource ownership per capita, forest coverage rate) and eco-environmental pressure (solid waste emission) have a strong grey correlation with ED, which greatly restricts economic development. In recent years, the province's GDP per capita has ranked the lowest in China, and there are 40 counties (districts) (total 86 counties (districts) in the province) have belonged to the national concentrated contiguous poverty-stricken areas before poverty alleviation, making rural revitalization is an important task. The coupling coordination degree is the lowest among the 3 provinces, and there is a great conflict between EEP and ED.

Therefore, when economic development and ecological environment background are both at a disadvantage, the old road of pollution first and treatment later cannot be taken. Gansu Province should give priority to ecology, develop and protect territorial space on the basis of ecological and green industries, realize EEP from the source, and then realize the value of ecological products, and promote the dynamic balance between EEP and ED (Appendix Table 5).

4.2. Discussions

The coupling and coordinated evaluation of economic development (ED) and ecological environment (EE) is a current research hotspot, but the most evaluation objects are different countries [40], cities [41,42], counties [43] and a single province [44], or only the coupling coordination evaluation of different provinces was carried out. No countermeasures are proposed to promote coordinated development [45]. Obviously, Research on the coupling and coordination by selecting several representative provinces is conducive to revealing the characteristics of regional differences for China, which has a vast territory and significant regional differences, thus provide a basis for putting forward countermeasures and suggestions according to local conditions.

In terms of coupling coordination evaluation methods, some of them adopt the analytic hierarchy process (AHP) [41], but the coupling coordination degree evaluation model is the most appropriate method. In the analysis of influencing factors, the geographical weighted regression (GWR) [42] and principal component analysis (PCA) [44] were adopted, while grey correlation degree model is advanced and adaptable for most of real system are grey systems (the factors in the system and their influence mechanism are partial clear). The black system (complete unclear) and the white system (complete clear) are very few, and the grey correlation degree model can clearly calculate the correlation degree of each factor to reflect its impact degree, while the principal component analysis can only calculate the cumulative impact degree of each factor.

Most studies put forward countermeasures to promote coordinated development, or from the aspects of labour education [46], tourism [47] and agriculture [43], while this study puts forward balanced strategies of economic development (ED) and ecological environment protection (EEP) from a new perspective of territorial spatial planning which has the characteristics of source, whole region and comprehensive. Of course, the implementation also needs the specific engineering space layout measures.

5. Conclusions

Balance is the mission of territorial spatial planning. Taking Zhejiang, Hunan and Gansu provinces in the eastern, central and western China as cases, the present balanced characteristics of the 3 provinces are revealed by using the coordinated coupling model and the grey correlation model, and the balanced strategy system of the 3 provinces are constructed in the new domain of provincial territorial spatial planning. The research conclusions are as follows:

(1) From 2010 to 2019, the coupling coordination degree and coordination type of the 3 provinces have been continuously improved, indicating that the balance has been continuously improved, but coordination type of the 3 provinces have obvious differences with a difference of one level. The current characteristics of balance are: Zhejiang Province is a primary coordination type restricted by ecological environment pressure, Hunan Province is a barely coordinated type restricted by the ecological environment pressure, Gansu Province is endangered disorder recession type restricted by eco-environmental conditions.
(2) From the aspects of balanced "three lines and one list" ecological environment zoning management and control strategy, spatial pattern strategy, ecological restoration and territory comprehensive consolidation strategy, regional coordination strategy and integration strategy, the ecological modernization planning strategy system of Zhejiang Province, the Ecological Industrialization planning strategy system of Hunan Province and the ecological fundamentalization strategy system of Gansu Province were constructed.
(3) The balance strategy system is of the characteristics of source, whole region and comprehensiveness, which can ensure that the territorial spatial planning truly becomes the spatial blueprint of sustainable development.

Data availability statement

Data included in article/supp. material/referenced in article.

CRediT authorship contribution statement

Dehua Mao: Writing - review & editing, Writing - original draft, Project administration, Methodology, Funding acquisition, Conceptualization. **Jingya Zhang:** Writing - original draft, Visualization, Data curation. **Huashan Lu:** Writing - original draft, Investigation, Data curation. **Ruizhi Guo:** Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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