VALUE REALIZATION ABILITY OF SUSTAINABLE ECOLOGICAL PRODUCTS IN THE YANGTZE RIVER ECONOMIC BELT, CHINA

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Abstract. Establishing the value realization mechanism of ecological products is of great significance to promote the coordination between ecological sustainability and economic development in the YREB (The Yangtze River Economic Belt) includes eleven provincial-level administrative regions, covering 11 provincial-level administrative regions including Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Chongqing, Sichuan, Yunnan, Guizhou, etc). Therefore, the evaluation of the ability to realize the value of ecological products is an important starting point to effectively promote the realization of the value of ecological products. This paper constructs the evaluation index system of provincial ecological product value realization ability from three dimensions: input ability, operation ability and organization ability. Using the entropy weight method and TOPSIS method, this paper empirically evaluates the value realization ability of ecological products in 2022, taking 11 provinces (municipalities) in China's Yangtze River Economic Belt as samples. The results show that the 11 provinces (municipalities) can be divided into three levels according to the ability of high, medium and low, and the different organization and operation ability of different regions. From the perspective of watershed distribution, the upstream region has a comparative advantage in the realization of ecological product value, followed by the downstream region and weaker in the middle reaches. In general, the 11 provinces (municipalities) have a low ability to realize the value of ecological products. It is suggested that local governments should adopt differentiated competition strategy according to their own actual situation and industrial development strategy, optimize and adjust the mode of ecological product value realization, so as to promote the continuous improvement of ecological product value realization ability and promote regional high-quality development
Keywords: *entropy TOPSIS method, Yangtze River Economic Belt, ecological products, value realization*

Introduction

The Yangtze River Economic Belt, which spans three major regions in China, is one of the "three major strategies" that the state has focused on implementing. Its area accounts for 21.4% of the country, and its population and GDP both exceed 40% of the country. It is an important ecological security barrier area in China (Counsellors' Office of the State Council, 2022). In recent years, the Yangtze River Economic Belt has always placed the protection and restoration of the Yangtze River ecological environment in the first place, promoted development under the condition of ecological protection, and achieved a win-win situation for environmental protection and economic development. However, there are many problems in the Yangtze River basin, such as large investment in ecological protection and small income, and economic and social development is

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limited by ecological protection policies (Lei et al., 2022). It is urgent to study a new model of ecological economic development with the realization of ecological product value as the core.

To realize the value of ecological products, we must first sort out the advantages and disadvantages of ecological resources, calculate the number of three kinds of ecological assets, and evaluate their abilities in the development and value realization of ecological products, so as to gather resources with goals and focus, and develop and enhance these abilities (Wang et al., 2021). Therefore, the evaluation of eco-product value realization ability is an important starting point related to the local government capability to clearly see the differentiated distribution pattern of ecological resources in a certain region or even the whole country. Also, relative competitive advantages of resources should be acknowledged to develop the eco-product value realization path and model that is most suitable for their resource base, capacity state, industrial structure and development strategy on the basis of accurate positioning. Foreign scholars put forward the concept of "ecosystem services" (Costanza et al., 1997; Daily, 1997; Assessment, 2005; Cairns, 1997), in recent years, the concept of eco-products in China has attracted much academic attention (Jin and Lu, 2021), and the practice of eco-product value realization has been in full swing all over the country. However, there has been a gap in the method research and tool development of quantitative evaluation of eco-product value realization ability, which has restricted the further development of the theory and practice of eco-product value realization in China. In view of this, based on the concept of "two mountains", this paper constructs an evaluation index system of ecological product value realization ability suitable for provincial level based on the three dimensions of ecological product input ability, operation ability and organization ability. Moreover, it establishes an entropy weight-—TOPSIS model, systematically develops the evaluation system of ecological product value realization, and conducts empirical analysis with 11 provinces (municipalities) in the Yangtze River Economic Belt as the research object. This paper makes a comparative analysis of the characteristics and differences in the ability to realize the value of ecological products in the upper, middle and lower reaches of the Yangtze River Economic Belt. The aim is to provide decision-making reference for optimizing the allocation of ecological resources, transforming and upgrading ecological industries, and perfecting the mechanism to realize the value of ecological products, thus contributing to the harmonious development of ecology, economy, politics and civilization in other regions of China.

Overview of the research area

As the largest river in Asia and China, the Yangtze River flows through 11 provinces (municipalities) in the east, middle and west of China (see *Fig. 1*), with complex landforms and diverse ecosystems. The water resources amount to 1.286 cubic meter, and there are 658 national nature reserves. It is an important biological gene treasure house and ecological security barrier area in China. It is an important space carrier for China to promote the realization of the value of ecological products., which has important guiding significance for other regions. Therefore, this paper selects 11 provinces (municipalities) in the Yangtze River Economic Belt as samples.

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Figure 1. *Map of China with purple shading indicating the non-YREB provinces (municipalities) and blue indicating the YREB provinces (municipalities)*

Theoretical basis and literature review

Before the concept of ecological products was put forward, the concept of ecosystem services was generally recognized. Ecosystem service refers to the welfare that human beings get from the ecosystem, including supply service, adjustment service, cultural service and support service (Peng et al., 2017). The original definition of eco-products comes from the National Planning of Main Functional Zones. It is a pure natural product with the attribute of ecosystem service, including fresh air, clean water and pleasant climate. Later, the connotation of this concept was continuously expanded. At present, ecological products include not only the pure natural part produced by the ecosystem, but also products jointly developed by human beings and nature, such as agriculture, forestry, animal husbandry and fishery products, and even products with ecological labels through environmental protection, green and clean technologies, such as new energy vehicles (Liao et al., 2021). According to the classic case of eco-product value realization published by the Ministry of Natural Resources, eco-products can realize value transformation through market path (such as eco-industry), non-market path (such as ecological compensation) and mixed path (such as property right transaction). To sum up, this paper defines ecological products as products and services that take natural ecological resources as raw materials and bring value to human development through natural transformation or human production.

The realization of the value of ecological products is the mechanism and process of applying Marxist ecological view of nature to the practice of ecological civilization construction, and it is committed to the mutual transformation and coordinated development of ecology and economy. The realization of the value of ecological products can help ecological poverty alleviation. By implementing ecological engineering, ecological compensation, providing ecological public welfare posts, developing ecological characteristic industries, and relocating to other places, some green mountains in underdeveloped areas can be effectively transformed into Jinshan Yinshan (Hu and Wang, 2021). China scholars have done a lot of research on the mechanism and path to realize the value of eco-products. For example, Zhang Ying and others believe that the supply of ecological products in China has obvious institutional attributes, and its three transformation paths of creation, maintenance, improvement and restoration are essentially government institutional arrangements, emphasizing the important role of

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government forces in realizing the value of ecological products (Zhang et al., 2016). Li Hongwei and others put forward that we can strengthen the construction of eco-product value realization mechanism from the aspects of property right management, value accounting, eco-industrial operation and capitalization operation, and diversified ecological compensation (Li et al., 2020). Dong Zhanfeng and others divided the realization of ecological product value into two mechanisms, namely, protecting beautiful green water and green mountains and making Jinshan Yinshan bigger, and constructed two models of protecting beautiful green water and green mountains and restoring ecological protection, and nine models of making Jinshan Yinshan bigger around industrial ecologicalization and ecological industrialization (Dong et al., 2020). Zhang Linbo and others analyzed nearly 100 cases at home and abroad, and concluded 8 categories and 22 sub-categories of eco-product value realization models (Zhang et al., 2019), including ecological protection compensation, ecological rights and interests transaction, resource property right transfer, resource quota transaction, ecological carrier premium, business development and utilization, regional collaborative development and ecological capital income, covering almost all paths of eco-product value realization at present.

On the practical level, in order to monitor and evaluate the progress of ecological civilization construction, the China Municipal Government has successively developed evaluation tools such as green development index, demonstration index of ecological civilization construction and two mountains index. Among them, the green development index includes 56 evaluation indexes in seven dimensions, such as resource utilization, environmental governance, environmental quality, ecological protection, growth quality, green life and public satisfaction (Guan and Han, 2020). Guided by promoting the formation of green development mode and green lifestyle and improving the quality of ecological environment, the evaluation indicators of national demonstration counties and cities for ecological civilization construction cover six aspects: ecological space, ecological economy, ecological environment, ecological life, ecological system and ecological culture (Ministry of Ecology and Environment, 2023); The evaluation index of “two mountains” formulated by the Ministry of Ecology and Environment includes three aspects: building green mountains and green hills, promoting the transformation of “two mountains” and establishing a long-term mechanism, and 20 specific indicators are selected. Compared with the evaluation target of eco-product value realization ability, the two-mountain index has more reference in the construction of index system: compared with the green development index, the two-mountain index pays more attention to the economic benefits of eco-industry; Compared with the demonstration index of ecological civilization construction, which focuses on social sustainable development and people’s healthy life, the two mountains index directly points to the protection of ecological environment and the realization of ecological benefits. Of course, the “Two Mountains Index” cannot be directly used for reference and applied to the evaluation of eco-product value realization ability, because: on the one hand, there is still a big difference between them in concept, and the “Two Mountains Index” emphasizes more on the static accounting of resources and benefits, while the evaluation of eco-product value realization ability should be a dynamic evaluation of ability, which is attached to a process-the input, organization and operation process of eco-product value realization (Li and Chen, 2021); On the other hand, the evaluation index system of “Two Mountains Index” is more suitable for the evaluation at the county and district levels, while the availability and comparability of

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index data at the provincial and municipal levels are weak, which is not conducive to the comprehensive comparison between different provinces and cities.

At the academic level, some scholars have also carried out related research. Based on the two purposes of ecology and economy, Li Haidong and others constructed the evaluation index system of two mountains from three aspects: ecological protection and restoration benefits, environmental pollution control benefits and two mountains transformation benefits (Li et al., 2020). Similarly, Xin Yueyou and others also constructed the practice effect index of the concept of two mountains from two dimensions: green mountains and green hills and Jinshan Yinshan (Xi and Zhang, 2021). In contrast, on the basis of ecology and economy, Pan Zhangkun added two aspects: people's livelihood development and security system, and constructed an evaluation index system for the development of the two mountains (Pan, 2019). The most perfect method system is that Chen Mei and others, based on the theory and method of ecosystem value accounting, constructed the accounting system of the gross output value of the two mountains' ecosystem from three dimensions of ecological product value, ecological adjustment value and ecological culture value, and tentatively evaluated the transformation effect of the two mountains with the sum of ecological product value and ecological culture value (Chen et al., 2021).

To sum up, the existing literature provides a lot of reference for this study, but there is still a research gap in the evaluation of eco-product value realization ability, especially for the evaluation of eco-product value realization ability in the provinces of the Yangtze River Economic Belt. This study has theoretical innovation significance in constructing the evaluation system of eco-product value realization ability at the provincial level from the perspective of the whole process.

Evaluation system

Logical framework

Based on the analysis of the experience of setting up Liangshan Bank in Lishui City, Zhejiang Province to help realize the value of ecological products and building regional public brands and promoting the value appreciation of ecological products in Fuzhou City, Jiangxi Province, it is concluded that the main tasks of realizing the value of ecological products include strengthening ecological protection, promoting pollution control, implementing industrial ecologicalization, promoting ecological industrialization, exploring innovative systems and implementing conventional systems. The specific requirements of these tasks provide reference for the selection of evaluation indicators in this paper.

In the evaluation system of the two mountains index, the core indicators are summarized into three dimensions: building green mountains, promoting the transformation of the two mountains and establishing a long-term mechanism. Because green water and green mountains are the resource base, the transformation of two mountains is the operation process, and the long-term mechanism is the organizational guarantee, the three aspects work together to build a systematic system of transformation from green water and green mountains to Jinshan Yinshan. However, as emphasized in the literature review, the philosophical basis of the evaluation of the two mountains index is the static view of resources and benefits, while the philosophical basis of the evaluation system of the value realization ability of ecological products to be constructed in this paper is the dynamic view of capabilities. According to the dynamic capability theory,

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capabilities can be divided into three types: zero-order capability, first-order capability and second-order capability: zero-order capability refers to the capability supported by basic resources and on which the system depends; First-order ability is the ability to operate and use existing resources to realize the value of resources; Second-order ability refers to the ability of the system to adapt to the external environment, reorganize resources and rebuild the ability system (Huang et al., 2009). Using this logic for reference, the realization ability of eco-product value is decomposed into three elements: input is the foundation, operation is the key, organization is the guarantee, and input ability plus organization ability provides support for the mechanism of operation ability. Only when the three elements work together can the realization of eco-product value be truly promoted. There is a close relationship between the three kinds of ability elements and practical tasks: input ability is closely related to tasks such as strengthening ecological protection and promoting pollution control, organizational ability is related to tasks such as exploring innovative systems and implementing conventional systems, and operational ability is related to tasks such as industrial ecologicalization and ecological industrialization. Therefore, the comprehensive ability is set as the target layer, the three ability elements are set as the criterion layer, and the related tasks are set as the index layer. Based on this, the idea is expanded, and considering the possibility of obtaining the index data through the statistical yearbook, the evaluation index system of the value realization ability of provincial ecological products is developed with clear design logic, strict structure and both scientific and feasible.

Index system

Input ability

Ecological natural resources are the material basis for realizing the value of ecological products and the essence of the value and function of ecological products. Input capacity is the government's efforts in improving the supply capacity of natural resources in order to expand green mountains and green rivers. Dong Zhanfeng and others believe that there are two different ways to strengthen the green mountains and green hills: ecological protection and restoration and pollution control. On the one hand, through artificial ecological restoration channels such as water control, soil control and sand control, the resource stock of protected ecological areas such as forests and wetlands can be improved, and the ecology can be protected and restored to consolidate the family's bottom; On the other hand, it is necessary to control environmental pollution and improve environmental quality from the aspects of domestic garbage and sewage treatment. On the issue of pollution control, in addition to industrial and domestic pollution control, we also need to consider key tasks such as ecological restoration of abandoned mines in the Yangtze River Economic Belt (Dong et al., 2020). In view of the above considerations, combined with the availability of index data, we choose the newly-increased soil erosion control area, the controllable desertification land control rate, the forest coverage rate and the wetland protection rate as the observation indicators for ecological protection, while the harmless treatment rate of domestic garbage, the sewage treatment rate and the newly-increased mine restoration area as the observation indicators for pollution control.

Operational capability

Industrial economic benefit is the direct value embodiment of ecological products. The National Environmental Protection Conference in 2018 proposed to speed up the

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establishment and improvement of an eco-economic system with industrial ecologicalization and ecological industrialization as the main body. Industrial ecologicalization requires the transformation and upgrading of three industries and the acceleration of the green transformation and upgrading of traditional industries in accordance with the concept of ecologicalization. Specifically, the focus of industrial ecologicalization includes agricultural ecologicalization and industrial ecologicalization: agricultural ecologicalization refers to introducing the concept of ecological protection as much as possible in the process of agricultural production, reducing the use of pesticides and fertilizers and saving water resources; Industrial ecology refers to reducing the emission of waste gas, waste water and waste and saving energy in industrial production. Therefore, the measurement indicators of industrial ecologicalization include pesticide consumption per unit cultivated land area, chemical fertilizer consumption per unit cultivated land area, energy consumption per unit GDP, and the ratio of industrial solid waste production to industrial output value. Ecological industrialization requires carrying out ecological capitalization management in accordance with the concept of socialization and marketization, promoting the transformation of ecological resources into ecological capital and ecological assets, and promoting the virtuous cycle of ecological and economic development (Chen, 2018). In the development of eco-industry, we focus on eco-agriculture, eco-industry and eco-tourism to build and operate. Among them, eco-industry includes agricultural and sideline food processing, food manufacturing, wood processing, furniture manufacturing, wine, beverage, refined tea manufacturing and other industries derived from ecological resources. Here, the proportion of the total operating income of the above processing and manufacturing industries to the industrial output value is selected as the measurement index of eco-industry. On the basis of the development of tertiary industry, the value added brought by the brand premium of ecological products is also considered. Therefore, we choose the ratio between the number of geographical indications of agricultural products and agricultural output value, the ratio of eco-industrial operating income to industrial output value, the ratio of tourism operating income to GDP in A-level scenic spots, and the ratio of tourist passenger turnover to GDP to measure the development ability of eco-industrialization from three aspects: eco-industry, eco-industry and eco-tourism.

Organizational ability

Using the evaluation index system of "Two Mountains Index" for reference, organizational ability is divided into two aspects: innovative system and conventional system. Innovation system is an innovation policy issued by the government to promote the value realization of eco-products, and it is the main basis and focus of promoting and implementing the value realization scheme of regional eco-products. The innovation system determines the professional planning and special mobilization ability of provincial governments in the strategy and action of realizing the value of ecological products. Conventional system is the general system of the government in natural resources, ecology and environment, which determines the social mobilization ability of local governments for ecological and environmental protection. At present, the innovation system of local governments in realizing the value of eco-products focuses on pilot areas and demonstration cases, carbon emission trading mechanism and the construction of "two mountains" bases, so its measurement indicators are the number of typical cases selected for realizing the value of eco-industry, whether it is a carbon emission trading area and the number of "Lucid waters and lush mountains are invaluable assets" practice

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and innovation bases; The conventional system focuses on the system construction of environmental protection, pollutant discharge monitoring and spot check, so the number of local environmental protection laws and regulations promulgated in that year, the number of key pollutant discharge units that have implemented automatic monitoring, and the ratio of the number of pollution sources randomly selected by daily supervision to the number of pollution sources included in the daily supervision random check information base are selected as its observation indicators. Among them, the number of local environmental protection laws and regulations, as an intermediate index, reflects the moderation of the number of environmental protection laws and regulations.

In the construction of three-dimensional indicators, we draw lessons from the green development index, ecological index, two-mountain index and other index systems designed by relevant state departments, but at the same time we also take into account the logic and characteristics of the ability to realize the value of ecological products. In order to ensure the availability of indicator data, most of the selected indicators are indicators that can be directly or indirectly calculated through statistical yearbooks and statistical bulletins; In order to improve the comparability of data between indicators, most indicators are expressed by ratio indicators rather than scale indicators; In order to ensure the independence of index data, correlation test and causal logic analysis were carried out after obtaining the index data, and no unexplained high correlation coefficient was found in each index layer. In a word, we followed the principles of scientificity, conciseness, hierarchy, independence, comparability and the combination of qualitative and quantitative (Peng et al., 2017), and finally built an evaluation index system of ecological product value realization ability, which includes 1 target layer, 3 criteria layers, 6 indicators layers and 33 observation indicators, as shown in *Table 1*.

Table 1. *Evaluation index system of eco-product value realization ability*

Target layer	Criterion layer	Index layer	Observation index	Indicator attribute	Comprehensive weight
Compre-hensive ability to realize the value of ecological products	Input capacity (0.242)	Ecological protection (0.138)	New soil erosion control area	Forward direction	0.03
			Governance rate of desertified land	Forward direction	0.049
			Forest coverage rate	Forward direction	0.023
			Wetland protection rate	Forward direction	0.011
			Proportion of protected areas to land area	Forward direction	0.015
			Forest pest control rate	Forward direction	0.01
		Pollution control (0.104)	Proportion of average excellent days of ambient air quality in prefecture-level cities	Forward direction	0.021
			Newly-increased mine restoration area	Forward direction	0.046
			Harmless treatment rate of domestic garbage	Forward direction	0.017
			Sewage treatment rate	Forward direction	0.02
	Operational capacity (0.381)	Industrial Ecology (0.224)	Proportion of water-saving irrigation area to cultivated land area	Forward direction	0.014
			Pesticide consumption per unit cultivated area	Negative direction	0.022
			Amount of chemical fertilizer used per unit cultivated area	Negative direction	0.022
			Water consumption per unit GDP	Negative direction	0.025

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			Energy consumption per unit of GDP	Negative direction	0.036
			Proportion of clean energy to total energy consumption	Forward direction	0.033
			The ratio of chemical oxygen demand discharge in wastewater (agriculture and industry) to agricultural and industrial output value	Negative direction	0.018
			The ratio of ammonia nitrogen emission in wastewater (agriculture and industry) to agricultural and industrial output value	Negative direction	0.018
			The ratio of sulfur dioxide emission in industrial waste gas to industrial output value	Negative direction	0.015
			Ratio of industrial general solid waste output to industrial output value	Negative direction	0.019
		Ecological industrialization (0.157)	Proportion of output value of agriculture, forestry, animal husbandry and fishery to GDP	Forward direction	0.027
			The ratio of the number of geographical indications of agricultural products to the agricultural output value	Forward direction	0.029
			Ratio of operating income of eco-industry to industrial output value	Forward direction	0.022
			Proportion of tourism operating income to GDP in A-level scenic spots	Forward direction	0.028
			Ratio of tourist passenger turnover to GDP	Forward direction	0.028
			Tourism brand development index	Forward direction	0.023
	Organizational ability (0.377)	Innovation system (0.248)	Number of selected typical cases of eco-industrial value realization	Forward direction	0.089
			Is it a carbon emission trading area?	Forward direction	0.092
			Number of practice and innovation bases selected as “Lucid waters and lush mountains are invaluable assets”	Forward direction	0.067
		Conventional system (0.129)	Number of local environmental protection laws and regulations promulgated in that year	Centre	0.061
			Number of key pollutant discharge units that have been automatically monitored	Forward direction	0.047
			The ratio of the number of pollution sources randomly selected by daily supervision to the number of pollution sources included in the daily supervision random inspection information base	Forward direction	0.021

Research areas and data sources

Considering that the implementation time of eco-product value realization policies in most provinces and cities is not long, and in order to improve the timeliness of data, we set the data time window as 2022, that is, we use cross-sectional data to carry out this research work. The main sources of data are China Statistical Yearbook, China Environmental Statistical Yearbook, China Environmental Yearbook, Ministry of Natural Resources and China Green Food Development Center. The data of the observation indicators under the innovation system indicators are adopted in the public reports of authoritative websites. A small amount of missing data shall be filled with data from neighboring provinces and cities or neighboring time.

Considering the influence of possible abnormal values of index data on the research results, we use winsorize method to truncate the original data. Furthermore, we use extreme value processing method to preprocess the index data. The calculation formula of extreme value processing method is as follows (Li et al., 2018):

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$$x_{ij}^{'} = \frac{x_{ij} - \min_{i=1}^{m} x_{ij}}{\max_{i=1}^{m} x_{ij} - \min_{i=1}^{m} x_{ij}} \quad \text{(Eq.1)}$$

Among them:

$x_{ij}^{'}$: It is the data of the j index of the I-th evaluation object after pretreatment;

x_{ij}: Is the original data. The forward index adopts *Equation 1* for data preprocessing; If it is a negative indicator, the formula is further used to reverse the direction; For the intermediate index, the average value of the index data is taken as the boundary, the data less than the average value is preprocessed according to the positive index, and the data greater than or equal to the average value is preprocessed according to the negative index $x_{ij}^{''} = 1\text{-}x_{ij}^{'}$.

Evaluation methods

In this paper, entropy weight–TOPSIS method is used to evaluate the value realization ability of ecological products.

Entropy weight method is an objective weighting method, and its advantage is that it can avoid the deviation caused by experts' subjective cognition and preference in determining the index weight. Its principle is to calculate the weight according to the variation degree of index data. The smaller the index information entropy, the greater the degree of index variation, the more information it provides, the stronger the explanatory role and resolution it can play in the evaluation, and the greater its weight (Ma et al., 2012). In this study, all the index data are quantized, and the number of evaluation objects is large, which meets the calculation requirements of entropy weight method and can reflect the advantages of entropy weight method. The calculation formula of entropy weight method is as follows:

$$w_j = \frac{1+\sum_{i=1}^{m}\left[p_{ij}\ln(p_{ij})\right]}{\sum_{j=1}^{m}\left\{1+\sum_{i=1}^{m}\left[p_{ij}\ln(p_{ij})\right]\right\}} \quad \text{(Eq.2)}$$

Among them:

w_j : The weight of the j index;

$p_{ij} = x_{ij}^{'} \Big/ \sum_{i=1}^{m} x_{ij}^{'}$: The relative contribution of the I-th evaluation object on the J-th index.

TOPSIS method (double-base point method) is a multi-attribute decision-making method based on Euclidean distance calculation. Its advantage is to determine the double standard of the relationship between the advantages and disadvantages of evaluation objects by setting positive ideal points and negative ideal points, so as to get the evaluation results and ranking more scientifically and accurately (Zhang et al., 2021). Its principle is to calculate the distance between the evaluation object and the positive ideal point and the negative ideal point respectively, and construct the statistics of the closeness of the evaluation object according to the logic that is inversely proportional to the distance between the positive ideal point and the negative ideal point, and then rank and make decisions according to the closeness score. The higher the closeness, the better the scheme

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of the object. The evaluation of the ability to realize the value of ecological products needs to take into account not only the level and potential of each province, but also the basic conditions and internal constraints of the province's ability development, and find a balance between the ideal scheme and the actual situation, which is in line with the logic that TOPSIS method follows the doctrine of the mean and tries to find a compromise and all-round development scheme. In addition, compared with the analysis methods such as weighted average and grey correlation, TOPSIS method has the advantages of more comprehensive perspective and more rigorous logic, and the evaluation objects and indicators in this study meet the requirements of TOPSIS method in terms of quantity and attributes, which is highly adaptable to this method. The calculation formula of TOPSIS method is as follows:

$$c_i = \frac{\sqrt{\sum_{j=1}^{n}\left(v_{ij}-v_j^-\right)^2}}{\sqrt{\sum_{j=1}^{n}\left(v_{ij}-v_j^+\right)^2}+\sqrt{\sum_{j=1}^{n}\left(v_{ij}-v_j^-\right)^2}} \quad \text{(Eq.3)}$$

Among them:
c_i: the closeness of the I-th evaluation object, that is, the evaluation result;
$v_{ij} = w_j x_{ij}^{'}$: weighted data;
v_j^+, v_j^-: positive ideal solution and negative ideal solution. In this study, for the sake of simplicity, for the index data after data preprocessing, the positive ideal solution takes the maximum value of all indexes on each evaluation object, and the negative ideal solution takes the minimum value of all indexes on each evaluation object.

Weight

The weight of each index in the evaluation index system of eco-product value realization ability is calculated by entropy weight method, as shown in *Table 1*. The objective weight reflects the difference of index data, which can be reflected by the weight coefficient: (1) In terms of ecological protection, there are relatively large differences between provinces and cities in soil and water control and desertification land control; (2) In terms of pollution control, there are significant differences in the area of newly-added mine restoration in different provinces and cities, which may be related to geographical conditions, but it also reflects that different local governments have different attitudes towards mine restoration, but there are small differences in air quality, domestic garbage and sewage treatment, which should be related to the fact that these works have basically been included in the daily work scope of environmental protection and ecological civilization construction; (3) In terms of industrial ecologicalization, the weight of clean energy and energy consumption per unit GDP is relatively high, which shows that the development capacity of industrial ecologicalization in different regions is still relatively uneven; (4) In terms of eco-industrialization, the geographical indications of agricultural products and the tourism income of A-level scenic spots are relatively high, which shows that the quality improvement and brand building of eco-industry are more unbalanced; (5) In terms of innovation system, the weights of two indicators, such as classic cases and carbon emission trading areas, are on the high side, indicating that some measures taken by the central and ministerial governments will widen the capacity gap between regions; (6) In terms of conventional system, the number of local environmental laws and regulations is the largest, indicating that different provincial and municipal governments

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attach great importance to environmental protection. Among the six criteria levels, the innovation system has the highest weight and is more explanatory than the conventional system; Ecological protection is more differentiated than pollution control; Industrial ecologicalization is more different than ecological industrialization. A comprehensive comparison of the weights of input ability, operational ability and organizational ability shows that the index weights of operational ability and organizational ability are almost the same and higher than input ability, so operational ability and organizational ability are identified as the key components to promote the value realization of regional ecological products.

Empirical analysis

Using TOPSIS method, the evaluation results of the value realization ability of ecological products in 11 provinces (municipalities) in the Yangtze River Economic Belt in 2022 are obtained (see *Table 2*). The average comprehensive water value of eco-product value realization capacity of each province and city is 0.434, and the average input capacity, operation capacity and organization capacity are 0.422, 0.429 and 0.319, respectively, which are all lower than 0.5, indicating that there is still much room for improvement in eco-product value realization capacity of most provinces and cities, and the overall construction level is not high enough at present. Among the 11 provinces (municipalities) in the Yangtze River Economic Belt, the top three provinces and cities are Chongqing (0.591), Jiangsu (0.49) and Hubei (0.484). Even these provinces and cities with relatively excellent performance have low comprehensive ability, and only Chongqing in the 11 provinces (municipalities) in the Yangtze River Economic Belt exceeds 0.5. However, relatively speaking, they all do have innovative measures and achieved practical results in realizing the value of ecological products. For example, At present, there are 8 pilot areas in China Carbon Emission Trade Exchange, including Chongqing and Wuhan. Jiangsu was selected among the classic cases of eco-product value realization announced by the Ministry of Natural Resources, ranking first among the 11 provinces (municipalities) in the Yangtze River Economic Belt, with outstanding eco-product value realization ability. The evaluation results of the provinces and cities with achievements listed in the classic cases announced by the Ministry of Natural Resources rank in the middle and upper reaches of the country, which confirms the scientific and effective evaluation system in this study to some extent. The last three provinces and cities are Yunnan (0.353), Hunan (0.326) and Anhui (0.268). Anhui and Hunan are particularly weak in organizational ability, while operational ability is the shortcoming of Ningxia.

We arrange the comprehensive ability to realize the value of ecological products in descending order of closeness (see *Fig. 2*), and divide the 11 provinces (municipalities) in the Yangtze River Economic Belt into three grades by using the natural breakpoint method, which are defined as high-level, medium-level and low-level areas respectively. The advanced areas are 3: Chongqing, Jiangsu and Hubei; There are 4 medium-sized areas: Shanghai, Zhejiang, Guizhou and Jiangxi; There are four low-level districts: Sichuan, Yunnan, Hunan and Anhui. As can be seen from *Figure 1*, the organizational capacity of the provinces and cities in higher education regions shows significant comparative advantages, while the input capacity of the other two provinces is relatively small except Chongqing. Chongqing, as a municipality directly under the central government, has a relatively large investment capacity, mainly because its area

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is relatively small, which magnifies the government's investment in ecological management. However, the investment capacity of other provinces is small, which implies that the improvement of the ability to realize the value of ecological products should be based on resource conditions and ecological products, but in fact, it is more important in terms of strategy, policy and system, which needs the government's great attention and strategic drive. The main disadvantages of middle-level provinces and cities compared with higher-level regions are also reflected in organizational ability. Judging from the evaluation results, there are two separate development trends in the middle-sized provinces and cities: the upper-middle regions, such as Shanghai and Zhejiang, have a small difference in the three capabilities and a relatively balanced development, and are actively improving the organizational capabilities of eco-products, striving to build more "two mountains" practice bases and excavating more rich realization cases. The middle and lower regions, such as Guizhou and Jiangxi, have absolute advantages in investment capacity, ranking first and second, that is, they are more inclined to invest in people, talents, materials and other resources to protect green mountains and green rivers, but the difference between the three capacities is large, with the investment capacity of Guizhou being 5.7 times that of the organization and that of Jiangxi being 3.5 times; The low-level provinces generally have obvious low investment ability and organizational ability, but they mainly rely on operational ability to support the value realization mechanism of ecological products. This is in line with the actual situation. According to observation, low-level provinces, such as Sichuan and Yunnan, are located in the southwest border of China, with relatively remote geographical location, general ecological environment and unfavorable ecological resources. These disadvantages make their ecological products insufficient, which limits the sustainable development of ecological product value realization. In addition, the organizational capacity of low-level areas is insufficient, and the government has not played a good supporting role in the innovation system and conventional system of realizing the value of ecological products. This is because, to a certain extent, they still have short-sighted behavior and pursue the quick realization of the value of ecological products, so they generally attach priority to the development and improvement of operational capabilities, and then enhance their investment and organizational capabilities. However, this vicious circle may further limit their development in realizing the value of ecological products in the future.

We re-analyze the ecological product value realization capacity of 11 provinces (municipalities) in the Yangtze River Economic Belt according to the upstream, middle and downstream, and the results are shown in *Table 3*. From the analysis of the average value of the three regions, the comprehensive ability to realize the value of ecological products is upstream, downstream and midstream in turn, and there are great differences among provinces in each region. As far as the comprehensive ability to realize ecological products is concerned, Chongqing in the upstream region ranks first with 0.591, while Yunnan ranks ninth with 0.353. Hubei in the middle reaches ranked third with 0.487, while Hunan ranked tenth with 0.326. Jiangsu in the downstream area is 0.49, ranking second, while Anhui It is 0.268. , ranked last, which fully shows that the work of realizing the value of ecological products has entered the stage of full-scale deployment from local pilot exploration, but it has not shown obvious agglomeration and convergence effects, indicating that the spillover effect of the promotion and development of the value realization ability of ecological products is not obvious.

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Table 2. *Evaluation results and ranking of ecological product value realization ability of 11 provinces (municipalities) in Yangtze River Economic Belt*

Province (city)	Comprehensive ability		Input capacity		Operational capability		Organizing ability	
	Degree of closeness	Ranking	Degree of closeness	Ranking	Degree of closeness	Ranking	Degree of closeness	Ranking
Chongqing	0.591	One	0.613	Three	0.422	Six	0.615	One
Jiangsu (Province)	0.49	2	0.221	10	0.323	11	0.529	2
Hubei (Province)	0.487	Three	0.373	Six	0.447	Five	0.496	Three
Shanghai	0.479	Four	0.564	Four	0.399	Seven	0.356	Six
Zhejiang (Province)	0.471	Five	0.369	Seven	0.451	Four	0.481	Four
Guizhou (Province)	0.457	Six	0.622	2	0.551	One	0.109	11
Jiangxi	0.436	Seven	0.626	One	0.392	Eight	0.188	Seven
Sichuan (Province)	0.412	Eight	0.219	11	0.493	2	0.363	Five
Yunnan (Province)	0.353	Nine	0.447	Five	0.391	Nine	0.138	Eight
Hunan	0.326	10	0.319	Nine	0.485	Three	0.113	10
Anhui (Province)	0.268	11	0.249	Eight	0.369	10	0.125	Nine
Average/mean value	0.432	—	0.421	—	0.429	—	0.315	—

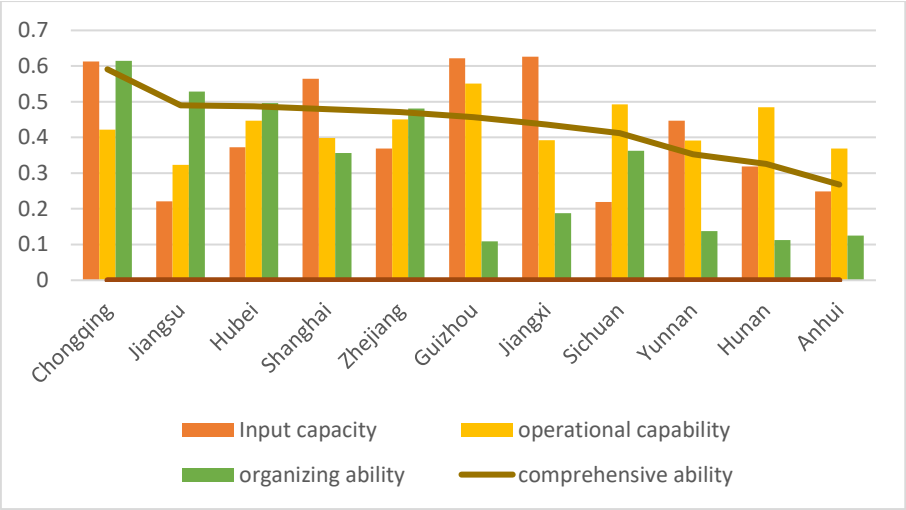

Figure 2. *Evaluation results of ecological product value realization ability in 11 provinces (municipalities) of Yangtze River Economic Belt (descending order)*

Table 3. *Evaluation results of ecological product value realization ability in sub-basins of 11 provinces (municipalities) in the Yangtze River Economic Belt*

Province (city)		Comprehensive ability		Input capacity		Operational capability		Organizing ability	
		Degree of closeness	Ranking	Degree of closeness	Ranking	Degree of closeness	Ranking	Degree of closeness	Ranking
Lower reaches	Shanghai	0.479	Four	0.564	Four	0.399	Seven	0.356	Six
	Jiangsu (Province)	0.49	2	0.221	10	0.323	11	0.529	2
	Anhui (Province)	0.268	11	0.249	Eight	0.369	10	0.125	Nine
	Zhejiang (Province)	0.471	Five	0.369	Seven	0.451	Four	0.481	Four
	Average/mean value	0.427	—	0.351	—	0.385	—	0.373	—

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Middle reaches	Jiangxi	0.436	Seven	0.626	One	0.392	Eight	0.188	Seven
	Hubei (Province)	0.487	Three	0.373	Six	0.447	Five	0.496	Three
	Hunan	0.326	10	0.319	Nine	0.485	Three	0.113	10
	Average/mean value	0.416	—	0.439	—	0.441		0.266	—
Upstream	Chongqing	0.591	One	0.613	Three	0.422	Six	0.615	One
	Sichuan (Province)	0.412	Eight	0.219	11	0.493	2	0.363	Five
	Guizhou (Province)	0.457	Six	0.622	2	0.551	One	0.109	11
	Yunnan (Province)	0.353	Nine	0.447	Five	0.391	Nine	0.138	Eight
	Average/mean value	0.453	—	0.475	—	0.464		0.306	
	Average/mean value	0.432	—	0.421	—	0.429	—	0.315	—

Conclusion

Under the background that the country is vigorously promoting the high-quality development strategy and all regions are striving to establish and improve the value realization mechanism of eco-products, constructing the evaluation system of the value realization ability of eco-products can provide theoretical reference and practical tools for optimizing the design of eco-product value realization promotion schemes and cultivating and improving the value realization ability of eco-products in various regions, which has important application guiding value. On the basis of developing the evaluation index system of eco-product value realization in provinces, this study empirically evaluates the eco-product value realization ability of 11 provinces (municipalities) in the Yangtze River Economic Belt in 2022 by using the entropy weight TOPSIS method, which makes up the gap in the evaluation field of eco-product value realization ability in terms of index design, method and model construction, and has certain theoretical innovation contributions. The research results make us more clearly understand the spatial pattern of the eco-product value realization ability in the Yangtze River Economic Belt, and explore the advantages and disadvantages of the upstream, middle and downstream provinces and cities in the eco-product value realization ability and their core and bottleneck elements, which can provide guidance for the provinces and cities to strategically adjust the eco-product value realization mechanism and path in the future.

After research, this paper mainly draws the following five conclusions:

The realization mechanism of eco-product value needs the joint promotion of input ability, organizational ability and operational ability, and the synergy of the three can make the comprehensive ability reach a higher level.

Provinces and cities with high comprehensive ability generally show outstanding organizational ability, while provinces and cities with low comprehensive ability are mostly caught in a vicious circle trap. They are at a disadvantage in investment ability and organizational ability, but they often hope to realize the rapid value realization of ecological products by cultivating operational ability, and obtaining short-term benefits may damage the healthy and sustainable development of ecological economy.

Each province and city can construct an evaluation index system of eco-product value realization ability from three aspects: input ability, organization ability and operation ability, and can implement scientific evaluation by using entropy TOPSIS method.

On the whole, the comprehensive level of eco-product value realization ability in China is low, and there is no obvious agglomeration effect in the region, which indicates that there is no spillover mechanism.

The upstream region occupies a relative advantage in the ability to realize the value of ecological products, followed by the downstream region, while the provinces and cities

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in the middle reaches are generally weak in the ability to realize the value of ecological products.

Based on the above conclusions, we put forward the following five suggestions for each region to continuously improve the value realization ability of ecological products in the future:

Local governments should comprehensively and fully improve the ability to realize the value of ecological products from three elements: input ability, organizational ability and operational ability, especially, they should give full play to the government's strength and make full efforts to cultivate and enhance organizational ability.

To develop the mechanism and cultivate the ability to realize the value of ecological products, we should have a long-term vision, the government should act and the society should invest, and we should not over-develop and utilize ecological resources just by operation.

All provinces and cities should fully investigate and verify the stock and structure of ecological resources, accurately evaluate their own advantages and disadvantages and relative positions in realizing the value of ecological products, and thus formulate a promotion plan for realizing the value of ecological products that is suitable for their own ecological resources and industrial economic conditions.

All provinces and cities should give full play to their learning ability and make use of the spillover and complementary effects of neighboring regions to seek cross-regional coordinated development, so as to win the development opportunity of realizing the value of ecological products in a larger vision and layout. Finally, the provinces and cities in the western and northeastern regions suggest vigorously improving the bottleneck problem of low input capacity and organizational capacity. The central region should learn more from the eastern region, while most provinces and cities in the eastern region still have room for improvement in input capacity and operational capacity.

In this paper, an evaluation system of eco-product value realization ability is constructed. The ranking of the ability results of provinces (municipalities and autonomous regions) verifies the practicability and scientificity of the evaluation index system, but it also reflects some limitations that may exist and need attention in the application process. First, the accuracy of indicators, there may be overlapping between the criteria layers. For example, although the input ability and operation ability are different in emphasis, they are both mixed with the natural resource base representing "green mountains and green hills" and the human, material and financial support representing "Jinshan Yinshan", while the organizational ability gives institutional guarantee to ecology and economy, so the three cannot be completely separated. The second is the rationality of weight distribution. Entropy weight method assigns weights according to the difference of index data, and it cannot highlight the importance of basic and important indicators with little discrimination. For example, according to experience, the forest coverage index will be more universal and important than the desertification control index in the context of realizing the value of ecological products, but the difference in desertification control among provinces and cities is greater than the difference in forest coverage, which leads to the heavy weight of the desertification control rate index. In the application of evaluation, we should pay attention to these problems and make some adjustments according to the actual situation and needs. For example, if we fine-tune the index weight according to the expert's opinion, we will get a more realistic evaluation result.

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From the academic research level, this study also has some shortcomings. First, due to the availability of data, the time window of this study is only one year, and the cross-sectional data cannot support us to dynamically analyze the progress of different provinces and cities in realizing the value of ecological products. Secondly, limited by the availability of data, the evaluation index system of this study does not adopt completely qualitative indicators, and the quantitative indicators mainly rely on yearbook and official publicly reported data. To some extent, some indicators are omitted, such as land premium, green finance and other eco-economic benefits. In the future, we will continue to develop and improve the width and depth of index data and do more sound research to better meet the decision-making reference needs at the provincial level.

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