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Research on development level and spatial distribution characteristics of state-owned forest farms in China

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Abstract

Purpose – The aim of this study is to depict the spatial pattern of the development level of China's state-owned forest farms, thereby providing theoretical reference and empirical evidence for the improvement of the corresponding development policies.

Design/methodology/approach – A development evaluation index system was established in this paper to comprehensively measure the development level of China's state-owned forest farms based on the Pressure-State-Response (PSR) model analysis framework and the actual situation of state-owned forest farms by using the entropy weight - technique for order preference by similarity to an ideal solution (entropy weight TOPSIS) evaluation method and exploratory spatial analysis method.

Findings – Studies show that the state-owned forest farms in China are generally not well developed. The pressure system that represents the input level displays an apparent restrictive effect on provinces whose comprehensive score <0.15. The response system, which represents development dynamism, has an apparent restrictive function on the provinces whose comprehensive score is 0.35. In terms of the specific spatial characteristics, the V-shape displayed by southwest–northwest and southeast–northwest has an inward trend of gradual reduction, with high-low agglomeration and low-low agglomeration correlation effects as well as apparent basin characteristics.

Originality/value – In this paper, the development level and spatial pattern of state-owned forest farms in China were accurately depicted, and the development path support and decision-making basis were provided for improving the overall development level of state-owned forest farms in China.

Keywords State-owned forest farms, Spatial characteristics analysis, Entropy weight -technique for order preference by similarity to an ideal solution (entropy weight TOPSIS) evaluation method, Index system

Paper type Research paper

1. Introduction

Forests, as the most productive terrestrial ecosystems in the world, are quite important for sustaining life on earth (Shi, 2011). At the 71st United Nations General Assembly, the *United Nations Strategic Plan for Forests (2017–2030)* was deliberated and adopted, which, as the first global forest development strategy made in the name of the United Nations, demonstrated that the international community attached great importance to forestry. As a major forestry country with world influence, China has carried out unprecedented forestry protection and ecological construction, increasing the forest coverage from 18.21% in 2007 to

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23.04% in 2020, increasing the forest stock to over 17.5 billion cubic meters (State Administration of Forestry and Grassland, 2020) and making the plantation area rank the first in the world for many years, thus making an important contribution to the realization of global forest strategic objectives. In the early days of the founding of the People's Republic of China, state-owned forest farms were established in the state-owned barren hills and wasteland suitable for forests by means of state investment, for protecting and cultivating forest resources and improving the ecological environment (Huang *et al.*, 2020). Up to now, after continuous reform, adjustment and scientific management, state-owned forest farms have formed an important part of China's forestry, with the highest quality forest resources and the most important ecological security barrier and forest resource base in China. In 2020, according to the national policy, the state-owned forest farms completed the comprehensive determination of functional orientation and management attributes, and 95.5% of the forest farms were identified as public benefit forest farms (General Office of the State Council, 2020), which defined the functional orientation of protecting forest resources and providing high-quality ecological services. The development of state-owned forest farms will be of great significance to the protection of China's forest resources and ecological protection construction; at the same time, it will make great contributions to the protection of world forest resources. At present, however, there are no scientific quantitative studies on the development level of state-owned forest farms in China, and it is difficult to have a comprehensive understanding of their current development status, which makes it difficult to put forward targeted suggestions for further development of state-owned forest farms. Therefore, making a reasonable evaluation plan, evaluating the development level of China's state-owned forest farms and clarifying the current development status of China's state-owned forest farms are of great practical significance and forward-looking significance for promoting the further development of state-owned forest farms and forestry in China.

As shown by the global development trend, more ownership and control rights of natural resources have been transferred from the state to local communities and individual families. The different subjects of property rights have made the research on state-owned forest farms learn less from foreign theories. As a form of forestry management organization in China, many scholars have conducted qualitative and quantitative studies and achieved fruitful results. Therefore, it is necessary to summarize and sort out the previous studies in China and find the methods and theories that can be used for reference.

State-owned forest farms, as special areas dominated by forest resources, should be collaboratively developed at the economic value-added dimension, social prosperity dimension and ecological health dimension, which has become the consensus of many scholars (Wang and Wang, 2011). However, since there are different development stages, the development focus has changed in stages, making it difficult to achieve the reasonable state. For example, before 1997, the development focus was to serve the economic construction and realize extensive economic development in China by cutting down forest resources (Wang, 2006); while since 1997, ecological protection has become the main theme of China's forestry development, and the way of harvesting natural forests to obtain forest resources has been abandoned. Therefore, the policy of banning logging of natural forests was gradually implemented, and ecological protection became absolutely prominent until 2017 when logging of natural forests was completely stopped (Yan, 2018). However, the ban on cutting natural forests has had a lasting impact on the development of state-owned forest farms relying on timber cutting and processing industries as economic sources (Gu and Gao, 2002), and it is difficult to achieve economic development while undertaking the task of ecological protection. It is difficult for many forest farms to find a development path to coordinate economic development and ecological protection. In view of this problem, the Chinese government and forestry regulatory authorities have prepared policies for support, and the state-owned forest farms identified as public benefit properties have been fully supported by

the state finance. Although this method can solve the survival problem of forest farms, it cannot solve the fundamental problem of coordinated development of forest farms. It has become an inevitable requirement for developing state-owned forest farms to realize the all-round development of economy, society and ecology. Measuring the development level of state-owned forest farms comprehensively and objectively has become a problem explored by academic circles. Therefore, in recent years, many scholars have made multi-angle studies on the development status of state-owned forest farms (Shi and Yu, 2014; Luo *et al.*, 2016).

At present, qualitative studies on state-owned forest farms have been extensively conducted, most of which systematically discussed certain policies, and explored the possible impact of the implementation of such policies on state-owned forest farms. In quantitative studies, there are mainly three research ideas: First, the development level of forest farms should be evaluated according to the single development dimension. Many scholars have analyzed China's state-owned forest farms from the aspects of performance, employees' sense of gain and differences of poor forest farms (Huang, 2021; Xu, 2021). Second, the development level of a specific forest farm should be systematically evaluated based on the current specific situation of the research object (Qu *et al.*, 2019; Liu *et al.*, 2019a; Wu *et al.*, 2021), but the research results are not applicable to other forest farms. Finally, an index system for development policies should be prepared, and then typical forest farms should be selected for trial evaluation. Sustainable management level (Xu, 2008; Zhang *et al.*, 2010) and modernization development level (Liu *et al.*, 2016, 2019b) are the most widely used evaluation criteria at present. However, the connotation of sustainable management and modernization development has not been fully understood, and it is not scientific to take it as an evaluation standard, which depends entirely on the professional knowledge and self-understanding of researchers.

It can be seen that although the current studies have achieved certain results, there are still some problems. First of all, the construction of the evaluation system is mostly based on theoretical description, and there is less application of analysis framework, making the quantitative analysis of state-owned forest farms less scientific and explanatory. Second, the research perspective is mostly limited to a specific forest farm, and there are few measurement standards and methods designed and demonstrated based on the national dimension, making it difficult to measure the comparative development level of China's state-owned forest farms. Finally, the traditional forest farm evaluation studies often ignored the spatial characteristics and imbalance, and the neglect of spatial factors would make the previous studies' lack of in-depth discussion on the development status of state-owned forest farms. Therefore, based on the panel data of China's state-owned forest farms from 2013 to 2017, the evaluation index system is established based on the analysis framework of Pressure-State-Response (PSR) model, and the development level of China's state-owned forest farms is evaluated based on the entropy weight -technique for order preference by similarity to an ideal solution (entropy weight TOPSIS), and then the spatial distribution characteristics are analyzed according to the evaluation results, so as to depict the spatial pattern of the development level of China's state-owned forest farms, thereby providing theoretical reference and empirical evidence for the improvement of the corresponding development policies.

2. Establishment of comprehensive development level index system for China's state-owned forest farms

The complexity of interrelation among economy, society and ecosystem of state-owned forest farm makes it a multifaceted and multilevel complex problem to evaluate its overall development (Wang and Wang, 2011). Such a complicated problem is generally solved by constructing an index system (Kotrla and Prčík, 2014; Nagel-Myers *et al.*, 2013). As concluded

in the previous studies, the high-level development of state-owned forest farms should be all-round and dynamic, which is specifically reflected in four aspects: "complete infrastructure construction, sufficient talent resources reserve, good economic environment and abundant forest resources" (Tian *et al.*, 2008; Zhang *et al.*, 2010). With respect to the high-level development of state-owned forest farms, infrastructure is the foundation; infrastructure construction must meet the needs of daily management; and talent resources play a supporting role. The state-owned forest farm has a sufficient talent resources reserve and attraction can drive the further development of forest farms; and economic environment is the premise of their high-level development. In reality, it is difficult for China's state-owned forest farms to coordinate economic development and ecological construction (Zhou, 2008). Moreover, undertaking ecological tasks has become an important reason for the economic development of many forest farms. Therefore, a good economic environment can show that economic development and ecological construction tend to be coordinated. Forest resources, the core of high-level development of state-owned forest farms, are also the carriers for state-owned forest farms to play ecological functions and provide ecological services. The management level of forest resources directly affects the survival status of forest resources in forest farms, as well as the ecological construction level. Therefore, the index system will be constructed from four aspects: infrastructure construction, talent resources, economic environment and forest resources.

In the process of construction, in order to comprehensively measure the four aspects mentioned above, the established index system should reflect the current development status and the reasons for showing the current development status, as well as the effectiveness of taking corresponding measures for further development of state-owned forest farms. Therefore, in this study, Pressure-State-Response (PSR) model was used to build an index system that can reflect the above development skeleton; this model was established in the land quality index research jointly carried out by the World Bank, Food and Agriculture Organization, United Nations Development Programme and United Nations Environment Programme (Liao, 2002). As a conceptual framework, it consists of three parts, namely pressure, state and response, all of which are mutually causal, for answering the questions "Why did it happen?", "What happened?" and "What should I do?" (Zhou *et al.*, 2010). Sometimes, there is no clear boundary between the three parts. In the process of application, the pressure index, the state index and the response index must be considered together, rather than one index alone. This model could provide an idea of building an evaluation index system, which emphasizes that in the process of practical application, it should be supplemented, improved and flexibly used according to the specific situation of the research subject (Xu and Liu, 2009). Therefore, in this paper, the actual development requirements of state-owned forest farms were combined with Pressure-State-Response (PSR) model to construct an evaluation index system suitable for the development system of state-owned forest farms.

As shown in Figure 1, the state system represents the current development state of all aspects of state-owned forest farms. The state of infrastructure construction is measured by the construction level of water supply capacity, electricity supply capacity, roads accessibility, networks accessibility and houses repairing in state-owned forest farms. Since the functional goal of state-owned forest farms is to protect and cultivate forest resources, the requirement for infrastructure construction is different from that for urban infrastructure construction. In order to ensure that the ecosystem where the forest farm is located is minimally disturbed by the outside world, the level of infrastructure construction should meet the requirement of state-owned forest farms for carrying out necessary daily management activities. Therefore, as for the present situation of infrastructure development, the arithmetic average of water supply compliance rate, electricity supply compliance rate, road accessibility rate, Internet accessibility rate and repair rate of dilapidated houses

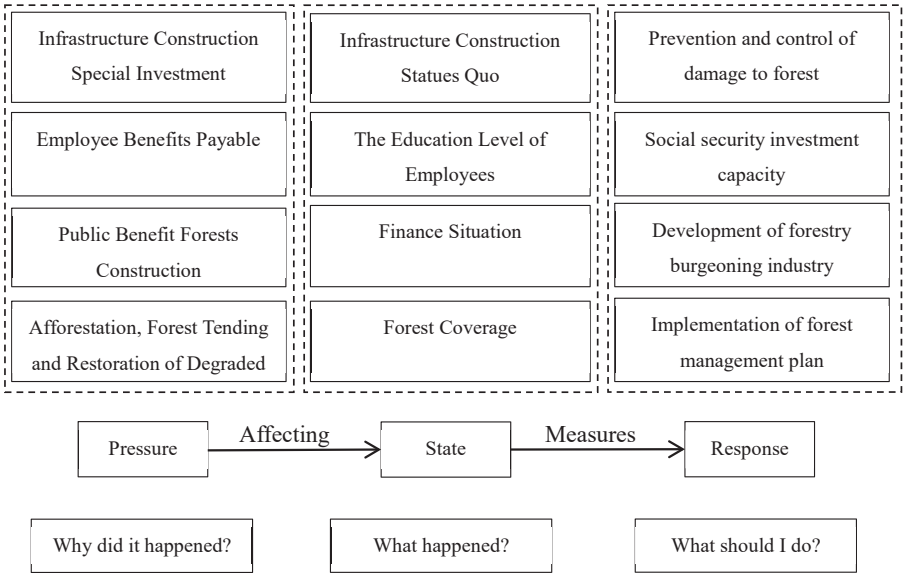

Figure 1.
Analysis framework of evaluation index system

necessary for forest farms to carry out management activities are selected as specific indicators, and this value is equal to 100%, which means that the present situation of infrastructure construction meets the development requirements. The state of talent resources reserve is measured by the education level of employees in state-owned forest farms. It is used to show whether the current state-owned forest farms have the ability to attract high-quality talents; economic environment is measured by the financial situation index of state-owned forest farms. This comes from the actual situation that economic structure of state-owned forest farm economy constitutes. The total revenue of a forest farm consists of two parts: one is grants from the central and the local government and the other is self-supporting income. The financial expenditure of a forest farm is all the spending for day-to-day management activities at the forest farm. According to the actual situation of state-owned forest farms in China, because of the difficulties in coordinating ecological construction and economic development, most forest farms cannot find available growth points but rely entirely on government grants. However, due to the limited economic strength of different places, the grants are often not enough to support all spending of a forest farm. Many forest farms are still unable to make ends meet. Therefore, the existing economic environment of state-owned forest farms is measured herein by the financial situation index calculated on the basis of total revenue and total expenditure, while the state of forest resources, measured by the forest coverage, is used to indicate the abundance of current forest resources.

The pressure system indicates the factors actually affecting the current development state of state-owned forest farms and answers the question "Why did it happen?". The level of special investment in infrastructure could affect the ability of infrastructure construction, so the per capita special investment in infrastructure was selected as the pressure index. Employee benefits payable could affect the attraction of forest farms to high-quality talents; and the main ecological task of state-owned forest farms is to construct public benefit forests. At present, it is difficult for state-owned forest farms to find available economic growth points from the construction of public welfare forests, and due to the poor self-supporting income, the farms can only survive by relying entirely on the financial support of the state and the

local government. The financial situation of the forest farm is not impressive. Therefore, the construction level of public benefit forests is an important reason for the restriction of the economic environment of state-owned forest farms. Therefore, the proportion of the area of public benefit forests was used to measure their construction level in this paper. Afforestation, forest tending and restoration of degraded forests, as important means for state-owned forest farms to protect and cultivate forest resources, are also important reasons resulting in the present state of forests.

The response system indicates what state-owned forest farms can do in response to the development status quo. As for infrastructure construction, in the *Reform Plan of State-owned Forest Farm*, China's forestry regulatory authorities clearly pointed out that it was necessary to support the further development of infrastructure construction of state-owned forest farms and accelerate the infrastructure construction for forest fire prevention and forest biological disaster control. Therefore, the arithmetic average of fire monitoring coverage and forest biological disaster control rate was used to measure the response level of infrastructure construction in state-owned forest farms. In terms of talent resources, state-owned forest farms can improve the treatment of employees by improving their social security investment capacity, thus helping to reduce the obstacles of talent inflow to a certain extent. Therefore, the per capita social security investment was used to measure the response level of talent resources in state-owned forest farms. As for economic environment, for alleviating the conflict between economic development and ecological construction, forestry burgeoning industry should be developed, including forest tourism and forest health care. On the basis of ecological construction, the ecological service supply capacity of forest resources can be brought into full play to realize economic development. Therefore, in this study, the total output per capita of forest tourism and ecological services was used to measure the economic development response level of state-owned forest farms. In terms of forest management, China's forestry regulatory authorities formulated *National Forest Management Plan (2016–2050)*, in which, the importance of improving forest quality and strictly implementing forest management plan was clearly pointed out. Therefore, the implementation rate of forest management plan was used to measure the response level of management of forest resources in state-owned forest farms.

According to the above analysis, the index system for development level of state-owned forest farms in China is finally constructed. The calculation method of specific indicators is shown in Table 1.

3. Methods

3.1 Regional overview and data sources

State-owned forest farms form an important foundation for ecological construction and forest resource protection in China. As shown in data of State Administration of Forestry and Grassland, the state-owned forest farms have 750,000 employees (including 480,000 on-the-job employees), the forest area of 44,666,700 hectares and forest stock of 2.34 billion cubic meters, accounting for 23 and 17% respectively of the total forest area and forest stock in China; and the forest coverage reaches the average level of 70% (Chen *et al.*, 2020). Since the implementation of reform in state-owned forest farms, remarkable development has been made in all fields, and all forest farms have kept up with the pace of poverty alleviation and got rid of poverty in China.

In terms of data sources, based on the actual investigation data of 4,855 forest farms in 28 provinces in China collected by the Research Group of State-owned Forest Farm Management and Reform of the State Administration of Forestry and Grassland from 2013 to 2017, the sample size was determined as 24,275.

System layer	Index layer	Calculation method
Pressure	Per capita special investment in infrastructure construction	Special investment in infrastructure construction/Number of staff in service
	The mean of employee benefits payable	Total employee benefits payable/(Number of staff in service + Number of retired workers)
	Public benefit forests area ratio	Total area of national and local public benefit forests/Forest land area
	Per capita total area of afforestation, forest tending and restoration of degraded forests	Total area of afforestation, forest tending and restoration of degraded forests/Staff on active duty
State	Infrastructure construction status quo	The arithmetic average of water supply compliance rate, electricity supply compliance rate, road accessibility rate, internet accessibility rate and repair rate of dilapidated houses
	The education level of employees	Number of employees with associate degree or above/Number of staff in service
	Finance situation index	Number of state-owned forest farms where income exceeds expenditure/Number of forest farms where income is less than expenditure
	Forest coverage	Forest coverage
Response	Construction level of prevention and control of damage to forest	The arithmetic average of fire monitoring coverage and forest biological disaster control rate
	Per capita social security investment	Total input of endowment insurance, medical insurance and social insurance/Staff in service + Retired workers
	Per capita gross output value of forestry burgeoning industry	Gross output value of forest tourism and ecosystem services/Number of staff in service
	Implementation level of forest management plan	Implementation rate of forest management plan

Note(s): Afforestation includes artificial afforestation and aerial seeding afforestation, excluding closing the land for reforestation; reforestation includes artificial reforestation of timber forest, excluding short rotation timber forest

Table 1.
China's state-owned forest farms development level index system

3.2 Comprehensive evaluation method

3.2.1 Entropy weight TOPSIS evaluation model. Entropy weight TOPSIS method is an evaluation method that combines entropy weight method with TOPSIS method. After data standardization, entropy weight method was used to weigh the indexes, and then evaluate the development level of evaluation objects according to the distance between indexes and the optimal solution and the worst solution.

3.2.1.1 Standardization and evaluation matrix. If j indexes of the index system in i provinces is evaluated, the index matrix is constructed as follows:

$$X = (x_{ij})_{m \times n} (i = 1, 2, \ldots, m; j = 1, 2, \ldots, n)$$

where, $m = 28$ and $n = 12$. Since the selected indicators in the index system have positive and negative attributes (public benefit forests area ratio is a negative attribute indicator), they should be standardized. The positive and negative attributes should be standardized as follows:

$$x_{ij}^{+} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}}, \; x_{ij}^{-} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}}$$

where, x'_{ij} is the standardized value. The standardized index matrix is:

$$X' = \left(x'_{ij}\right)_{m\times n} (i = 1, 2, ..., m; j = 1, 2, ..., n)$$

3.2.1.2 Entropy weight method for calculating weight. Li Lei *et al.* (2014) found that, by calculating the proportion p_{ij}, entropy e_j and utility information d_j of each index, the weight w_j can be calculated as:

$$p_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}},\ i = 1, 2, ..., \mathrm{m},\ j = 1, 2..., n$$

$$e_j = -\frac{1}{\ln(m)} \sum_{i=1}^{m} p_{ij} \ln\left(p_{ij}\right)$$

$$d_j = 1 - e_j$$

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}$$

3.2.1.3 Entropy TOPSIS for determining the development level. Based on the index weight w_j and the standardized matrix$X' = (x'_{ij})_{m\times n}$, the weighted decision evaluation matrix $A = (a_{ij})_{m\times n}$ can be established, where $a_{ij} = \omega_{ij} x'_{ij}$. The distances D^+ and D^- from each evaluation index to the optimal solution A^+ and the worst solution A^- can be calculated as:

$$A^+ = \{\max A_{ij} | j = 1, 2, ..., n\} = \left\{A_1^+, A_2^+, ..., A_n^+\right\}$$

$$A^- = \{\min A_{ij} | j = 1, 2, ..., n\} = \left\{A_1^-, A_2^-, ..., A_n^-\right\}$$

$$D^+ = \sqrt{\sum_{J=1}^{n} \left(A_{ij} - A_j^+\right)^2}$$

$$D^- = \sqrt{\sum_{J=1}^{n} \left(A_{ij} - A_j^-\right)^2}$$

Therefore, the development level of state-owned forest farms in each province C_i can be calculated using:

$$C_i = \frac{D_i^-}{D_i^- + D_i^+};\ C_i \in [0, 1]$$

3.2.2 Quadratic weighting method. During the study, China's forestry regulatory authorities selected some provinces to carry out pilot policies related to forestry or state-owned forest farms, which indicated that the policy-related indicators may fluctuate greatly. For example, from 2014 to 2015, provinces such as Gansu, Hebei and Anhui were taken as pilot provinces to explore new reform schemes of state-owned forest farms. The basic data used to calculate the indicators, such as infrastructure investment, have changed greatly. However, upon determination of the reform schemes, and after the inclusion of the infrastructure investment funds in the financial plan of the government at the same level, the level of investment

changed greatly again, thus the representativeness of the indicators in 2015 was relatively low, making it difficult to express the actual investment capacity of the related provinces in infrastructure in 2015. In order to weaken the influence of similar experimental policies on measuring the actual development level of state-owned forest farms, the calculation results from 2013 to 2017 were weighted in time dimension. Therefore, according to the empowerment principle of "laying more stress on the present than on the past" (Huang, 2008; Yuan and Qi, 2013), and the lessons from the relevant study conducted by Yuan and Qi (2013), the empowerment results should meet the following requirements:

$$\begin{cases} \omega_{t+1} \geq \omega_t \geq 0 \\ \sum_{t=1}^{5} \omega_t = 1 \\ \omega_t = \gamma \exp(\lambda t) \quad \gamma,\ \lambda > 0 \end{cases}$$

where, ω_t is the weight of time dimension, $t = 1, 2, \ldots 5$, γ is the adjustment coefficient, for ensuring the constant $\sum_{t=1}^{5} \omega_t = 1$, λ is the weighting factor and $\exp(\lambda t)$ is the time weighting function. The selection of λ is related to the time period, and the ratio of the last term to the first term, that is, the degree of importance d_q can be calculated as follows:

$$d_q = \frac{\omega_5}{\omega_1} = e^{\lambda(q-1)}$$

According to the study conducted by Huang (2008), when the time dimension is five years, it is appropriate for d_q to take e. At this time, λ is 0.25, and the adjustment coefficient γ can be calculated as 0.0888. Therefore, after the second weighting, the final comprehensive score F_i is:

$$F_i = \sum_{t=1}^{5} \omega_t \cdot C_{it} = \sum_{t=1}^{5} 0.0888 \exp(0.25t) \cdot C_{it}$$

3.2.3 Exploratory spatial analysis method. In order to clarify the spatial distribution characteristics of the development level of state-owned forest farms in China, the exploratory spatial analysis method was used in this study to describe the spatial characteristics. Global autocorrelation analysis (Moran's I), clustering and outlier analysis (Anselin Local Moran's I) are important analytical methods to study spatial correlation, with the calculation formulas as follows:

$$I = \frac{m \sum_{a=1}^{m} \sum_{b=1}^{m} W_{ab} \left(F_a - \overline{x}\right)\left(F_b - \overline{x}\right)}{\sum_{a=1}^{m} \sum_{b=1}^{m} W_{ab} \left(F_b - \overline{F}\right)^2}$$

$$I_a = \frac{m\left(F_a - \overline{F}\right)}{S_a^2} \sum_{b \neq a}^{m} W_{ab} \left(F_b - \overline{F}\right)$$

where, W_{ab} represents the spatial weight matrix of provinces a and b, F_a and F_b are the comprehensive score of provinces a and b respectively and $\overline{F}$ is the average of comprehensive scores. S_a^2 is the variance of the actual value of the index calculated as:

$$S_a^2 = \frac{\sum_{a=1}^{m} W_{ab}\left(F_a - \overline{F}\right)}{m}$$

4. Results and analysis

Based on the development evaluation index system of China's state-owned forest farms, the entropy weight TOPSIS method was adopted in this study. First, the development level of state-owned forest farms was comprehensively analyzed (Section 4.1). In this section, the comprehensive development level and development level of each development system (pressure, state and response system) are all calculated. It should be noted especially that the calculation method about each development system is identical with the comprehensive evaluation method, they will not be covered here. Only n is different; n is equal to the number of internal indicators of each system. In this paper, n of pressure, state and response system all equal to 4. After comprehensively analysis, the spatial heterogeneity analysis (Section 4.2) and spatial autocorrelation analysis (Section 4.3) were carried out on the development level of each development system (pressure, state and response system).

4.1 Analysis on development level of state-owned forest farms in China

By establishing the index system of development level of China's state-owned forest farms, the entropy TOPSIS method was used to calculate the development level and each development system, and obtained the score range of [0,1]. In order to know more about the development level of state-owned forest farms in China, the development level scores were divided in this paper. Based on the established index system, the state-owned forest farms meeting the requirements of complete infrastructure construction, sufficient talent resources reserve, good economic environment and abundant forest resources were deemed as more comprehensive and higher-level forest farms. Therefore, when dividing the development level, the related studies on regional development level and coordinated development evaluation could be referred, and the evaluation results could be divided into five levels based on the study conducted by Gao and Wang (2011) and Feng and Fan (2014). The score [0.75, 1] means high, [0.5, 0.75) means moderately high, [0.35, 0.5) means medium, [0.15, 0.35) means moderately low and [0, 0.15) means low. The specific calculation results are shown in Table 2.

As calculated based on the comprehensive score, the average score of the development level of China's state-owned forest farms is 0.274, being to right-skewed distribution obviously. Only nine provinces have higher scores than the average, accounting for 32.14%, and the overall development level could be further improved. Zhejiang province has the highest comprehensive score (0.647), and Gansu province has the lowest score (0.114), with a range of 0.533. There is a significant gap in the development level of state-owned forest farms in various provinces. Six provinces have comprehensive scores over 0.35, which is above the medium development level, accounting for only 21.43%; except for Beijing, all are southern provinces. At the same time, there are also five provinces at a low level (less than 0.15), all of which are northern provinces, indicating that the development level of state-owned forest farms in southern China is generally better than that in northern China. Therefore, it can be concluded that the development level of China's state-owned forest farms may mainly be affected by the following three aspects: First, the leadership is poor. The comprehensive scores of Zhejiang and Jiangsu provinces (representing the highest development level of China's state-owned forest farms) are 0.647 and 0.612, respectively, failing to reach the high level. The comprehensive scores of Beijing, Guizhou, Chongqing, Guangdong are [0.35, 0.50), being at a medium level. These provinces and autonomous regions could not lead the development of China's state-owned forest farms. Second, the support is weak. Of the forest

	Fi	F-rank	Pressure	P-rank	State	S-rank	Response	R-rank
Zhejiang	0.647	1	0.400	5	0.851	1	0.415	1
Jiangsu	0.612	2	0.323	12	0.848	2	0.396	2
Beijing	0.446	3	0.532	1	0.791	3	0.188	8
Guizhou	0.444	4	0.355	9	0.525	10	0.303	3
Chongqing	0.438	5	0.475	3	0.429	13	0.258	4
Guangdong	0.393	6	0.344	10	0.591	6	0.240	5
Xinjiang	0.346	7	0.521	2	0.311	18	0.088	19
GuangXi	0.327	8	0.395	6	0.651	4	0.117	12
Sichuan	0.300	9	0.217	15	0.464	11	0.219	6
Fujian	0.264	10	0.291	13	0.623	5	0.159	9
Heilongjiang	0.261	11	0.371	8	0.548	8	0.091	18
Qinghai	0.253	12	0.427	4	0.150	27	0.051	28
Anhui	0.249	13	0.159	21	0.183	24	0.206	7
Yunnan	0.248	14	0.393	7	0.178	26	0.077	22
Jilin	0.240	15	0.326	11	0.539	9	0.076	23
Shandong	0.231	16	0.154	22	0.451	12	0.132	11
Hainan	0.209	17	0.110	28	0.574	7	0.116	13
Hebei	0.209	18	0.260	14	0.291	20	0.086	21
Jiangxi	0.204	19	0.208	17	0.406	14	0.133	10
Shanxi	0.185	20	0.213	16	0.212	23	0.064	25
Henan	0.173	21	0.165	20	0.242	22	0.096	17
Hunan	0.171	22	0.142	23	0.312	17	0.107	14
Hubei	0.150	23	0.126	26	0.299	19	0.097	16
Liaoning	0.148	24	0.167	19	0.251	21	0.086	20
InnerMongolia	0.146	25	0.111	27	0.384	15	0.069	24
Ningxia	0.137	26	0.187	18	0.144	28	0.103	15
Shaanxi	0.132	27	0.135	25	0.378	16	0.059	26
Gansu	0.114	28	0.135	24	0.180	25	0.054	27

Table 2.
Evaluation results of development level of state-owned forest farms in China

farms, 60.71% are still at the moderately low development level, and the comprehensive score is between [0.15, 0.35), making it difficult to promote the overall improvement of the comprehensive development level of state-owned forest farms in China. China's state-owned forest farms have not formed a solid development foundation soon after getting rid of poverty. Third, there are low-level provinces. Of the provinces, 17.86% are at a low level of development, and there is still a big gap with other provinces in terms of infrastructure, talents resources, forest resources and economic environment, which lowers the overall development level of state-owned forest farms in China.

From the perspective of pressure system, the development level of pressure system of state-owned forest farms in China is 0.273, generally at the moderately low level. The difference between Beijing with the highest score (0.532) and Hainan with the lowest score (0.110) is 0.422, which indicates a big gap in terms of infrastructure investment, staff treatment and management and protection of forest resources, and they may be related to the economic strength of the regions of the state-owned forest farms. Except for Beijing, the scores of the pressure systems of Chongqing, Xinjiang and Qinghai were quite different from those of Ningxia and Gansu with lower scores. They are all provinces in the western region, indicating that apart from the influence of economic strength, the provinces have attached different importance to the development of state-owned forest farms, which have led to obvious differences in input levels. Moreover, with the gradual decrease of the comprehensive score, the restrictive role of the pressure system has become more obvious, and the ranking of regions with a comprehensive score less than 0.15 and the ranking of the pressure system have gradually tended to be consistent, suggesting that for provinces with low comprehensive levels, the increases of infrastructure investment, staff treatment and

management and protection of forest resources in state-owned forest farms is a point of penetration to improve the comprehensive development level.

From the perspective of state system, the average score of state system of China's state-owned forest farms is 0.422, with the range of 0.707. The development status of state-owned forest farms in different provinces and regions is obviously different. Three provinces have reached the high level, namely Zhejiang, Jiangsu and Beijing, indicating that they have realized comprehensive development in infrastructure construction, talent resources reserve, forest resources and economic operation, and the conflict between economic development and ecological construction is low, tending to be coordinated. However, the provinces at the bottom of the list, such as Ningxia, Qinghai, Yunnan and Gansu are currently in a poor state of development. Of these provinces, Ningxia and Gansu, located in ecologically fragile areas with poor resource endowment, combined with their pressure systems, have a low level of input, making the current development state poor; therefore, it is necessary to pay more attention to state-owned forest farms. However, the current development state of Qinghai and Yunnan fails to match the input level of their pressure systems, showing that in addition to ensuring the input level, the input-output efficiency should be ensured.

From the perspective of response system, the average score of response system of China's state-owned forest farms is only 0.146, indicating that the effectiveness of the measures taken by China's state-owned forest farms for future development is insufficient, the development vitality is not released, and the development will is not strong in the construction of forest disaster prevention and control capacity, development of forestry burgeoning industries, employee security investment and strict implementation of forest management plan. Only nine southern provinces have scores greater than or equal to 0.15, accounting for 32.14%. Moreover, with the increase of the comprehensive score, the constraint of the response system has become more obvious, and the regional ranking of the top six comprehensive scores (comprehensive scores is greater than or equal to 0.35) has become gradually consistent with that of the response system. For example, in Zhejiang and Jiangsu provinces, as the best developed areas of state-owned forest farms, their comprehensive development level is restricted by the scores of pressure system and response system. When the development state meets the development requirements, the willingness to further development would decline, and the input level in forest pest control, forest management and protection will not increase further. Therefore, for the provinces with higher comprehensive levels in China, the development vitality should be released and the proportion of input in response measures should be increased. And it is a key to achieve comprehensive scores in high development levels.

4.2 Spatial heterogeneity analysis of development level of state-owned forest farms in China

The overall evaluation of the development level of state-owned forest farms showed that the overall development level in the southern region is better than that in the northern region, but the spatial distribution characteristics of the comprehensive development level of state-owned forest farms have not been deeply discussed; therefore, it is difficult to understand the current spatial distribution state. Therefore, Jenks natural breakpoint classification method was used in this section to analyze the spatial heterogeneity of the comprehensive development level and the development level of each development system, as shown in Figure 2.

As shown in the spatial distribution of the development level of state-owned forest farms (Figure 2a), there is obvious spatial heterogeneity manifested in the downward trend of V-shape from southwest to northwest and southeast to northeast. The eastern coastal areas, with the strongest economic strength and the achievement of complete poverty alleviation, have the highest comprehensive development level, followed by Guangxi, Guizhou and

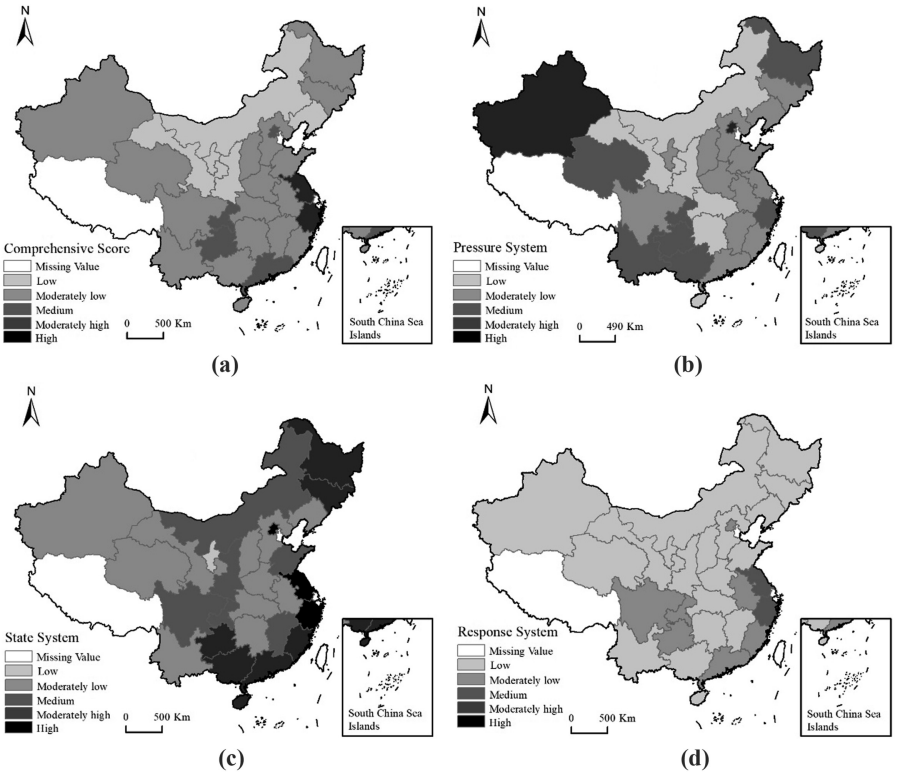

Figure 2.
Spatial differentiation of China's state-owned forest farm development level

Chongqing, and the north-central areas have the lowest comprehensive development level. The positive operation of the overall social and economic environment could drive the development of high value-added forestry industries, such as under-forest planting, forest tourism, recreation and health care to be in the forefront of China. In Southwest China, such as Guangxi, Guizhou and Chongqing, there have been rich and diverse forest resources since ancient times. Although there is a gap from coastal areas such as Zhejiang in economic strength, in recent years, Southwest China has paid more attention to forestry development, made great efforts in exploring natural resources landscape economy and realized a virtuous circle of the development of state-owned forest farms, thus achieving a better development level and greater development potential. However, the development level of state-owned forest farms in north-central and northeast areas such as Gansu, Inner Mongolia, Ningxia and Liaoning is still relatively low because of their location conditions. First of all, Gansu, Ningxia and Inner Mongolia along the Yellow River Basin lack forests and vegetation, making the ecological environment fragile. In recent years, although large-scale afforestation has greatly improved the ecological environment in these areas, the emphasis on the development of protective afforestation has created a big gap with other areas in infrastructure and industrial development. Moreover, the main employees in these areas are local residents, and employees with associate degree or above only constitute 28.49%. Although the employment problem of local residents has been solved to some extent, there is still no high attraction to high-quality talents. Second, the development of state-owned forest farms in Liaoning, with the best social-economic development in Northeast China, is slightly inferior to that in Heilongjiang and Jilin endowed with high forest resources, because most of the state-owned forest farms in Liaoning

province are located in the northwest and east of Liaoning province, while the northwest of Liaoning province belongs to the ecologically fragile mountainous area and the barren land area, and the east of Liaoning province belongs to the remote mountainous area with steep terrain, making it difficult to construct infrastructure. In addition, the freezing snow and various natural disasters caused by mountain torrents are far from enough to support the state-owned forest farms.

From the perspective of the spatial differentiation of the development level scores of each development system, the spatial heterogeneity is equally obvious. First of all, the spatial distribution of the pressure system (Figure 2b) is similar to that of the overall development level, showing a downward trend of V-shape from southwest to northwest and southeast to northeast. On the whole, the investment levels can be ranked as follows: Xinjiang Autonomous Region and Beijing > southwest and northeast > east > central and west-central. Beijing, as the capital of China, has strong economic strength and is in the forefront of China in infrastructure construction, staff treatment and forest management; so, it has high overall investment capacity. Xinjiang, as a border area of China, although there is a certain gap with inland areas of China in social and economic development, as early as 2003, it took the lead in exploring the reform of state-owned forest farms in China, making the development of state-owned forest farms a core of forestry development in Xinjiang. The ecological construction projects in recent 20 years, such as Natural Forest Protection Program, have provided a solid financial guarantee for the reform and construction of state-owned forest farms in Xinjiang, making the investment level of state-owned forest farms in Xinjiang rank the top in China. Southwest China and Northeast China, with high endowment of forest resources, have paid attention to forestry development for a long time. However, the pressure system scores in the central and west-central region such as Inner Mongolia, Gansu, Shannxi, Hubei and Hunan are all less than 0.15. It means that the investment level in above region is low, which must be improved.

As shown in the spatial distribution of the state system (Figure 2c), the regions can be ranked as follows in terms of development levels: the eastern coastal area and Beijing > the southwest and northeast areas > the northwest and east-central areas. Zhejiang and Jiangsu in the eastern coastal areas had the characteristics of water supply compliance rate, electricity supply compliance rate, road accessibility rate, Internet accessibility rate, repair rate of dilapidated houses up to 90% and about 70% forest coverage. In terms of economic environment, their finance situation index all exceed 1, which means that the forestry center is in an economic situation where revenues (including financial grants and self-supporting revenues) surpass expenditure and is in a good financial position. According to the current development state, the state-owned forest farms in these areas have initially shown the development state of complete infrastructure, good economic environment and abundant forest resources. The development state of state-owned forest farms in the southwest and northeast is not comprehensive, which have distance from that in the eastern coastal areas. Due to the complex geographical features, many forest farms in the southwest still have substandard drinking water and low road accessibility. However, there is satisfactory infrastructure construction in Northeast China, but with poor economic environment, the arithmetic average of Northeast China (Heilongjiang, Jilin and Liaoning) only have 0.273 in finance situation index in 2017. It means to be in an economic state where "Expenditure is greater than income"; as a traditional timber production base, the impact brought by the prohibition of natural forest cutting has not been eliminated. At the same time, the lagged overall social and economic development in Northeast China in recent years has made the economic environment of state-owned forest farms poor, affecting the development score. The state-owned forest farms in Northwest China, a backward region in China with fragile and complex natural environment, are in poor development. Although the input has narrowed the gap between state-owned forest farms in Northwest China and those in other

regions in recent years, there is still a long way to go. The current state of development of the central region, represented by Shanxi, Hebei and Jiangxi provinces, is consistent with its stress system score, indicating that increasing attention to state-owned forest farms and improving investment capacity are important means to improve the state of development.

Finally, as shown in the response system (Figure 2d), the spatial characteristics of coastal areas, Beijing and southwest areas are higher than those in other areas, and the overall level is obviously lower than other development systems. The east coast, Beijing and southwest regions are the most dynamic areas for the development of state-owned forest farms in China. Although the current development status of state-owned forest farms in Anhui province is at a poor level, the response system scores are in the forefront of China, indicating that state-owned forest farms in Anhui province have made efforts to explore the road of high-level development of state-owned forest farms. If the input level in forest tourism, forest economy and forest biological disaster control is strengthened, the economic pressure brought by the construction of public benefit forests can be alleviated, while the development level can be rapidly improved, and the state-owned forest farms can be quickly developed.

4.3 Spatial autocorrelation analysis of development level of state-owned forest farms in China

The law of geography indicates that all matters in space are interrelated, and their closeness would decrease with the increase of distance (Overmars *et al.*, 2003). Therefore, it is necessary to explore the spatial closeness of the comprehensive development level of state-owned forest farms in China. As analyzed, the global Moran's I index of the development level of state-owned forest farms in China is 0.437, and the p-value is 0.003, which has passed the significance test. It can be concluded that there is a spatial autocorrelation between the development levels of state-owned forest farms in China. The positive and negative correlation regions of global Moran's I cancel each other out, which will affect the accuracy of the measurement of spatial correlation, and local Moran's I should be performed for further verification. Anselin Moran's I method is used to analyze the development level of state-owned forest farms in local space and obtain local indicators of spatial association (LISA) agglomeration map.

As shown in Figure 3, the development level of state-owned forest farms is characterized by low-low agglomeration and high-low agglomeration, rather than high-high agglomeration and low-high agglomeration. Gansu, Ningxia, Inner Mongolia and Shanxi are characterized by low-low concentration, while the comprehensive development level of state-owned forest farms is characterized by overall low level, and the neighboring Sichuan province is characterized by high-low agglomeration, indicating that the correlation of the current development level of state-owned forest farms has not broken through the geographical distance, and the neighboring areas are closely related to each other. In addition, the above-mentioned provinces are all located along the Yellow River Basin, with obvious basin characteristics. Therefore, it suggests possible development ideas for promoting the overall improvement of the development level of China's state-owned forest farms: based on the similarity of regions and watersheds to which each province belongs, the development level of China's state-owned forest farms can be improved by strengthening intra-regional exchanges and mutual assistance, shortening the intra-regional development gap and realizing the overall development within the region.

5. Conclusions and implications

According to the empirical analysis results, this paper puts forward the following conclusions and implications for the development of state-owned forest farms in China: (1) The overall

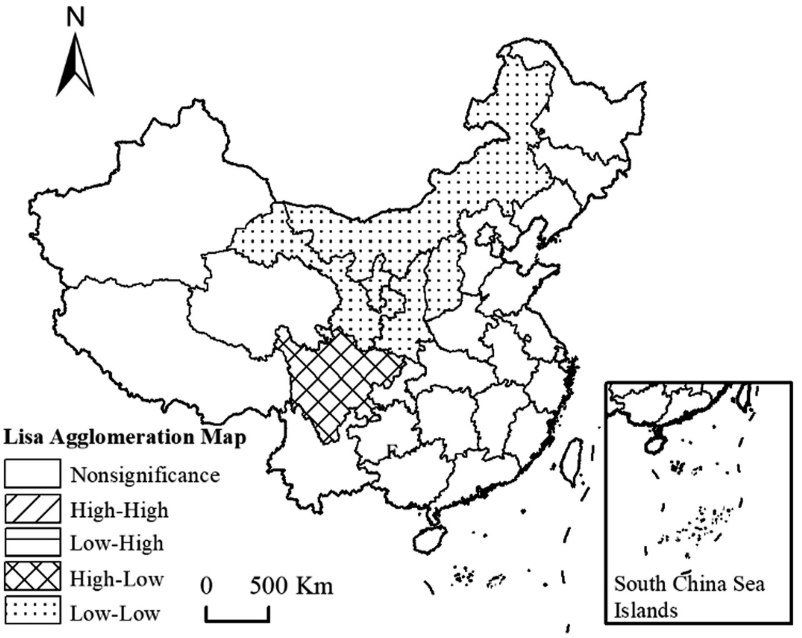

Figure 3.
Local indicators of spatial association (LISA) agglomeration map of state-owned forest farms development level

development level of state-owned forest farms in China is not high, and there are no provinces reaching the high development level. Zhejiang, Jiangsu and Beijing are in the forefront of the development, while Ningxia, Shaanxi and Gansu lag behind other regions. Combined with each development system, the pressure system representing the input level has obvious restrictive effect on the provinces with low development level, namely, those with comprehensive score less than 0.15, while the response system representing development vitality has obvious restrictive effect on those with comprehensive score greater than or equal to 0.35. Therefore, for provinces with a score less than 0.15, especially those with weak economic strength, in addition to the increase of the financial allocation of the government at the same level, the central regulatory authorities should increase subsidies and establish a supervision system for the use of funds, so as to form a support system with double guarantees of capital investment level and efficiency. At the same time, the provinces in the forefront of the development of state-owned forest farms should increase the input level of forest tourism and biological disaster prevention and control, release the vitality of development, take the lead in entering the stage of integrated development and play the leading role of radiation. (2) From the perspective of spatial distribution, there is obvious spatial heterogeneity and autocorrelation. On the whole, the development level of state-owned forest farms in the south is higher than that in the north, which is proved by the downward trend of V-shape in southwest–northwest and southeast–northeast. Low-low agglomeration areas are mainly distributed in Gansu, Inner Mongolia, Ningxia, Shanxi and Shaanxi. High-low agglomeration shows that Sichuan province is significantly related to low-low agglomeration areas, suggesting obvious location characteristics of the Yellow River Basin. Therefore, China's state-owned forest farms should strengthen inter-provincial co-construction based on location conditions and similarity of river basins, and the provinces with comparative development advantages should take the lead and give full play to the advantages of wide radiation coverage of the Yellow River Economic Belt; downstream areas within the river basin should drive the upstream areas, the eastern coast should drive the

inland areas, and the northwest region should seize the development opportunities of ecological protection and river basin co-construction and drive the northwest region through the southwest region; Beijing should drive North China and East China to improve the development path of Central China. If necessary, a "one-to-one" assistance mechanism and a high-quality forestry talent dispatching mechanism should be established to alleviate the flow obstacles of talent factors caused by location conditions, and help low-level state-owned forest farms to achieve rapid development in infrastructure construction, forest resource management and finally, to realize the overall development of China's state-owned forest farms.

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