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Evaluation of the Sustainable Forest Management Performance in Forestry Enterprises Based on a Hybrid Multi-Criteria Decision-Making Model: A Case Study in China

Deqiang Deng [1], Chenchen Ye [1,*], Kemeng Tong [1] and Jiayang Zhang [2]

[1] College of Economics and Management, Nanjing Forestry University, Nanjing, China.
[2] School of Economics and Management, Nanjing University of Science and Technology, Nanjing, China.
* Correspondence: ycc3258@163.com

Abstract: Sustainable Forest Management (SFM) can fully use forest resources and improve the economic, environmental and social sustainability of forest areas. Forestry enterprises play a crucial role in the implementation of SFM. To better play the role of forestry enterprises in implementing SFM, it is necessary to establish a comprehensive and reasonable performance evaluation model for SFM in forestry enterprises. However, the previous literature pays little attention to this research question. Taking the Triple Bottom Line (TBL) as a theoretical framework and the Montreal Process Criteria and Indicators (MP C&I) as a basis, this paper constructs an indicator system to evaluate the performance of SFM of forest enterprises from economic, social and environmental aspects. This paper applies the integrated MCDM method, i.e. the BWM method and the VIKOR method, to construct the methodological system for SFM performance evaluation of forestry enterprises. The effectiveness of this SFM performance evaluation model is then demonstrated through its application to a case study of forestry enterprises in China. Through the application of the model, this paper evaluates the enterprise's SFM performance over the five-year period 2017-2021 and proposes appropriate policy recommendations and improvements.

Keywords: forestry enterprise; sustainable forest management; triple bottom line; MCDM methodology

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1. Introduction

Since the United Nations Conference on Environment and Development (UNCED) explicitly stated in 1992 that all forest natural resources should be protected and sustainably managed [1], the concept of Sustainable Forest Management (SFM) has garnered significant attention from both academia and the general public. SFM has developed into the primary goal of global forest management, with a continuous emphasis on environmental protection and ecological health [2]. This concept has gained widespread recognition across all of the world. At the Asia-Pacific Economic Cooperation (APEC) Summit 2019, China made a declaration to integrate the development of ecological civilisation into its economic and social processes, aiming to achieve resource conservation and environmental protection. Following this commitment, China has consistently advocated for the target of "peak carbon and carbon neutrality" in 2020. Furthermore, China has been actively involved in global efforts to address climate change and achieve sustainable development, including the sustainable management of forest resources.

SFM is effective in maintaining the essential ecological functions of forests and biodiversity and monitoring anthropogenic activities that negatively impact the environment [3,4]. SFM is a core forest management concept and plays a significant role in ecological economic policies in European countries [5]. Furthermore, prior studies have evaluated SFM performance from various perspectives

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in different countries [6,7]. Given the wide range of aspects involved in SFM, some literature has been used to establish evaluation models to identify and evaluate management performance, providing information on SFM in terms of environmental, economic, and social aspects [8,9].

However, most of the previous studies on SFM have been conducted at the relatively macroscopic national and regional levels. In contrast, research on SFM at the microcosmic enterprise level is still ignored, unfortunately. In fact, forestry enterprises play a crucial role in the implementation of SFM. Firstly, forestry enterprises consist of two main parts: the business of forest management (e.g., afforestation, forest protection) and the production and processing of forest products. For forestry enterprises to develop sustainably, they must make rational use of and protect forest resources, minimise waste emissions from processing forest products, and fulfil their social responsibilities while achieving economic benefits. Forestry enterprises can reduce carbon emissions and promote the carbon cycle through forest cultivation, which can protect biodiversity and maintain forest ecosystems' viability. Secondly, forestry enterprises can promote forest recreation, tourism, and other services to support public production and consumption, thus creating socio-cultural value while protecting the ecological environment. SFM also requires a balance between the interests of forest natural resources and recognising the benefits and values that forests offer in various economic, social, and environmental dimensions. Finally, the objectives of sustainable development for forestry enterprises closely align with the objectives of SFM, because they both are focused on maintaining the health and sustainability of the forest ecosystem while using forest resources to meet economic and social needs. In short, SFM is essential for forestry enterprises. Therefore, this paper initially establishes an SFM performance evaluation model to help forestry enterprises translate strategy into action and offer predictive measures concerning their future performance, which expands the research field of SFM and serves as a reference for SFM at the enterprise level.

Currently, the dominant approach to evaluating SFM performance is the Montreal Process Criteria and Indicators (MP C&I) developed by the Canadian Council of Forest Ministers (CCFM). This indicator system is specifically designed to evaluate the performance of countries and regions concerning the SFM process. Although the C&I framework provides a robust mechanism and is recognised and used by many countries and regions, there are still shortcomings in its implementation and application. Firstly, the number of indicators is large and not well targeted, which increases the difficulty of obtaining data for some indicators and thus affects the evaluation results. Secondly, C&I focuses on national and regional levels, which may not accurately reflect the performance of individual enterprises and may not fully align with the evaluation requirements of SFM in forestry enterprises. Therefore, there is a need to reconstruct the traditional C&I to make them applicable to the performance evaluation of SFM in forestry enterprises. This paper builds upon the C&I and combines them with China's SFM standards and indicators to establish a more comprehensive and targeted evaluation system for forestry enterprises. This approach not only optimises the C&I by expanding their scope but also integrates the objectives of production and operation with SFM in forestry enterprises. It further enhances the optimisation of forest resource allocation within forestry enterprises.

In traditional SFM performance evaluation research, most researchers use the Analytic Hierarchy Process (AHP) to determine the weights of the indicator system. This method is simple, feasible, and easy to use. However, the AHP method requires stratification, which may artificially break the link among indicators and significantly increase the workload and research difficulty [10–12]. Therefore, this paper introduces the BWM method to obtain the weights of indicators. This method can effectively reduce the number of stratifications and comparisons, thereby reducing the workload. It also has a broader scope of application and is more capable of comprehensively and objectively establishing the evaluation indicator system of SFM in forestry enterprises. At the same time, the current literature on SFM mainly adopts the TOPSIS method to rank the weights of the identified indicators. However, this method can only obtain a unique optimal solution, which may not necessarily be the most ideal sought. Given this, this paper adopts the VIKOR method to rank the scenarios. The VIKOR method allows for comparing scenarios and ranking advantages and disadvantages to select a compromise solution with priorities that are closer to the ideal solution.

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Therefore, this method can overcome the shortcomings of the commonly used TOPSIS method and offers certain advantages.

In summary, this paper presents three main contributions. Firstly, it diverges from previous studies evaluating SFM performance at the national and regional levels. Instead, this study concentrates on evaluating the SFM performance of forestry enterprises. The research in this paper provides a new perspective on SFM and fills a gap in the previous literature. Second, an indicator system is constructed to evaluate the SFM performance of these enterprises. The indicator system uses the Triple Bottom Line as a theoretical framework and the Montreal Process C&I as a basis, encompassing economic, social, and environmental aspects. This paper designs a new indicator system based on the existing framework. The selected indicators are more specific, targeted, and suitable for enterprise-level research. Finally, the paper uses integrated MCDM methods, including the BWM and VIKOR methods, to evaluate the SFM performance, identifying problems in the implementation of SFM within forestry enterprises and proposing potential solutions. Compared to previous literature that uses a single method for performance evaluation, the hybrid model employed in this paper is more comprehensive. It can reduce subjective interference and allow the selection of an ideal compromise solution based on the actual context. So, the results obtained from this model are more robust and effective. This paper enriches the research on SFM and extends it to the micro level of enterprises. The model for SFM performance evaluation in forestry enterprises proposed in this paper can strengthen the management practices of forestry enterprises, which can help their development and contribution to the environment and society.

The rest of this paper is structured as follows: Section 2 reviews the relevant literature. Section 3 describes the indicator system for SFM performance evaluation in forestry enterprises. Section 4 introduces the methodology used for SFM performance evaluation. Section 5 presents a case study using a forestry enterprise in China. Section 6 shows conclusions.

2. Literature Review

2.1. Performance Evaluation of Sustainable Forest Management

The valuation of SFM is about the valuation of the forest system itself and the social and economic values that forestry provides to people. In 2003, the Canadian Council of Forest Ministers (CCFM) developed a set of national criteria and indicators based on the Montreal Process C&I [13]. The CCFM Criteria and Indicators Framework for SFM was revised in the same year and now includes 6 criteria and 47 indicators for SFM in Canada [14]. The purpose of the proposed SFM indicator framework is to reflect the environmental, economic and social components of SFM [9]. Therefore, to achieve this goal, SFM indicators are used to identify and evaluate management performance [8]. As the significance of SFM has increased in different organisations, SFM indicators have become elaborate, leading to the emergence of different indicator systems.

Although a range of indicators, such as the MP C&I, are recognised by all sectors of society, there are still some problems and challenges in evaluating current indicators of SFM. Firstly, the development of indicators for SFM has often been led and proposed by elite academics, which can give the impression that it is a purely technical or scientific exercise. In fact, SFM is fundamentally recognised as a moral, ethical issue [4]. Secondly, C&I frameworks typically adopt a top-down approach in identifying key measures of success in forest management [15–17]. However, this approach can introduce bias, as the subjective views of those creating the frameworks may influence the selection of indicators [18,19]. As a result, the chosen indicators may not fully and accurately reflect the implementation of SFM. Some scholars have suggested that while much indicator work relies on selecting a large number of detailed indicators, it is preferable to concentrate on a smaller number of indicators within the selected criteria. Prabhu et al. (2001) also argue that establishing thresholds for individual indicators is crucial, as they can potentially indicate critical transitions or inflection points in the system [20]. These thresholds include the point at which the system is irreversibly degraded.

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As noted by Parris and Kates (2003) [21], indicators of SFM can reflect various motivations, including decision-making, management, research, and analysis. These indicators also bridge the gap between science and policy [22]. Incorporating the Triple Bottom Line (TBL) theory can effectively address the complex causal relationships between multiple factors. By focusing on forestry enterprises, we can effectively tackle these issues. Therefore, it is important to construct a reasonable and accurate evaluation of SFM performance to achieve SFM.

2.2. Performance Evaluation of Sustainable Forest Management in Forestry Enterprises

There is a perception that forestry enterprises are generally regarded as environmentally friendly, without realising that they also cause pollution. China has been mainly concerned and widely criticised for using forest resources, energy consumption, high emissions, and water pollution [23]. Pollution from forestry enterprises is also a significant problem for China, especially in paper-related industries. Wastewater discharges from the pulp and paper industry have been criticised as a significant source of industrial and water pollution in China. China's State Environmental Protection Administration (SEPA) has closed at least 7,000 pulp and paper mills since 1997 [24]. In 2008 alone, 621 pulp and paper mills closed, and 8,000 were restructured. From a forestry enterprise's perspective, sustainable forest management involves integrating corporate and SFM objectives to achieve co-development of economic, social, environmental, and governance aspects.

Most currently available articles on research about SFM are focused on field tests of criteria and indicators systems for SFM at the local level. For instance, Mendoza and Prabhu (2003) [25] employed a multi-criteria analysis (MCA) approach to evaluate SFM using criteria and indicators [6]. They have conducted a case study in Kyrgyzstan, where they integrated four stakeholder preferences and employed criteria and indicators to evaluate SFM. Assuah et al. (2016) investigated the commitment of Wetzin'kwa Community Forest Corporation (WCFC) in British Columbia to sustainable management of its community forests and examined actions taken at the community forestry level to implement SFM [7]. However, evaluating SFM performance at the macro level is challenging in terms of operation and subsequent improvement. It is because SFM in forestry enterprises needs to promote the enterprises' economic, social, environmental, and governance aspects and achieve sustainable development of the forests themselves. Therefore, the performance of SFM cannot be adequately captured by a single characteristic, and a suitable multi-criteria indicator evaluation method for SFM in forestry enterprises should be established by comparing existing SFM performance methods.

2.3. Decision-Making Models for Sustainable Forest Management

In the literature on forest decision-making, MCDM methods have been used to tackle various issues such as harvest planning, forest biodiversity conservation, forest sustainability, regional planning, risk, and uncertainty [26]. One of the most widely used and prevalent techniques for structuring C&I sets is the Analytic Hierarchy Process (AHP), which was introduced by Saaty (1977, 1980) [27,28]. For instance, Mikkilä et al. (2005) employed the AHP technique to evaluate pulp and paper enterprises' corporate social performance in four countries [29]. Group AHP, a method extensively applied for preference analysis in complex multi-attribute problems, is also commonly used for strategic planning in the context of forest decision-making [30–33]. In a study conducted in Iran, Goushegir et al. (2009) used AHP to develop an indicator system for timber production and forest conservation in the Kheiroud-Kenar forest [34]. Zandebasiri and Parvin (2012) employed the pressure-state response (PSR) framework to identify the impacts of the Kohgiluye and Boir-Ahmad Tang-e SoolJ forests in the province of Tang-e SoolJ, which serve as key C&I for SFM [35].

However, it has been pointed out that while evaluating individual indicators may seem appropriate in a structural hierarchy, the interactions among indicators are not obvious [25]. As a result, many scholars have tried to overcome this limitation by designing and studying network structure as a feature of SFM evaluation models. Saaty (2004) proposed the Analytical Network Process (ANP), which assesses the overall cumulative importance of all indicators in an evaluation model by incorporating linkages and feedback into the decision-making system [36]. Although ANP may be a highly relevant tool in SFM assessment, there have been no published applications of ANP in forestry or forestry-related fields to date. Chung et al. (2005) compared the VIKOR, SAW method (Simple Weighted Approach), and the TOPSIS (Distance of Superiority and Inferiority Solutions), analysing each method's advantages, disadvantages, and scope. This analysis provided some guidelines and suggestions for selecting subsequent research methods [37]. Opricovic and Tzeng (2007) developed a VIKOR method that effectively enhances the accuracy of evaluation results based on preferences [38]. They demonstrated the advantages of expanding the VIKOR method by comparing it with the ELECTRE and TOPSIS methods. To address the issue of unequal criterion weights, Vahdani et al. (2010) and other researchers introduced the interval-valued fuzzy VIKOR method [39]. Additionally, some scholars have combined the AHP method with the VIKOR method to determine the weights using the AHP method and then employ the VIKOR method for efficient ranking.

Since constructing dimensions and indicator structures allows for a more comprehensive and detailed description and evaluation of various aspects of SFM, this paper adopts a Multi-Criteria Decision-Making (MCDM) approach. Specifically, it uses both the BWM and the VIKOR method to construct a model for evaluating the performance of SFM in forestry enterprises. The BWM method, which relies on judgment vectors to calculate priority, can be easily integrated with other MCDM methods to rank indicators' importance. On the other hand, the VIKOR method calculates the deviation between positive and negative ideal solutions and actual values based on indicator importance judgment, subsequently assigning ranks accordingly. Combining these two methods allows for a more robust construction of the performance evaluation model for SFM in forestry enterprises.

2.4. Brief Discussion on the Related Previous Literature

Much of the existing research on SFM has been conducted at international, national, and regional levels [6,25,40]. Although extensive work has been done on SFM, the implementation of SFM has often shifted the focus from the productive values of forests and their social and economic benefits to their environmental values and services [41]. This top-down approach to implementing SFM is less practical due to the large size of forests and the significant variation within the same region. Many criteria and indicators, such as the Montreal Process C&I, are primarily designed for national and regional assessments and come with numerous dimensions. Furthermore, the accuracy and accessibility of data for many of these indicators are not guaranteed. The original C&I are no longer applicable to assessing contemporary SFM performance. Therefore, starting SFM implementation at the enterprise level, focusing on forestry enterprises, can effectively reduce the number of indicators and dimensions. This approach allows obtaining more accurate data, which is essential for evaluating SFM performance. By doing so, forestry enterprises can improve their management of forest assets and facilitate better implementation of SFM.

Secondly, the current research on performance evaluation of forestry enterprises includes many relevant indicators, making it difficult to establish a unified approach. Some literature only focuses on indicators from a specific perspective, resulting in biased and incomplete evaluation results. To achieve sustainable development, a forestry enterprise should not solely concentrate on one aspect of its development but consider all dimensions comprehensively. This principle also applies to evaluating the SFM performance of forestry enterprises, where indicator selection should aim to reflect the three pillars of the SFM concept: economy, environment and society. Since indicators are interrelated and mutually influential, it is necessary to consider the economic, environmental, social, and interdimensional linkages. Moreover, these indicators need to be appropriate for the actual organisational units responsible for forest management [42]. The Triple Bottom Line (TBL) model based on the economic, social, and environmental dimensions allows for a comprehensive analysis of the performance of different dimensions of SFM in forestry enterprises while also considering the influences and relationships between these dimensions.

Thirdly, the current research method used to evaluate the performance of SFM is primarily Multi-Criteria Decision Making (MCDM). MCDM uses known information and data to rank alternatives and give the decision maker an optimal decision plan. This method allows for an intuitive reflection of the strengths and weaknesses of forestry enterprises in the process of SFM, as well as aiding enterprises in making targeted changes and improvements. When using the MCDM method, some studies combine it with the Analytic Hierarchy Process (AHP) to structure the MP C&I. However, the AHP approach does not offer new alternatives, and the need to explicitly stratify indicators can disrupt the connections between them. This disruption is particularly pronounced when there are many indicators, as the AHP method significantly increases the workload of data statistics and makes calculating weights more difficult. This paper, therefore, adopts the Best Worst Method (BWM) to score indicators using a numerical 1-9 scoring scale, similar to the AHP method [43]. However, the BWM procedure is much more straightforward and consistent than AHP. BWM only requires reference comparisons between all indicators and the selected optimal and worst indicators, respectively [43,44]. In previous literature, simple weighting methods were commonly used to compare options and obtain weights for indicator selection. With the advancement and improvement of research methods, some studies have started to choose other methods for program comparison, typically the TOPSIS and VIKOR methods. Compared to the TOPSIS method, which can only identify the unique optimal solution, the VIKOR method can identify a compromise solution with priorities closest to the solution in the ideal state. As a result, an increasing number of studies are using the VIKOR method to evaluate SFM.

In summary, previous literature on SFM primarily focuses on the macro, national and regional levels, with very few studies conducted at the micro level and even fewer studies specifically on forestry enterprises. However, forestry enterprises play a vital role in SFM. This paper aims to address the research gap by focusing on forestry enterprises as the primary research object, which enriches the related research in this field. Moreover, existing indicators on SFM are numerous but lack systematic and uniform standards. In contrast, this paper establishes a unified indicator system based on the existing framework and indicator system. This new system is more applicable to SFM at the enterprise level while also considering the unique national conditions. In addition, more and more literature has shifted from a single performance evaluation method to a mixed method and has gradually realised the limitations of the subjective evaluation method. As a result, researchers now tend to combine subjective and objective methods for a more comprehensive evaluation. The hybrid MDCM model (BWM and VIKOR method) used in this paper combines both qualitative and quantitative approaches. This model allows for consistent results with less information while exhibiting good robustness and effectiveness.

3. Performance Evaluation Indicator System for Sustainable Forest Management in Forestry Enterprises

The selection of indicators is crucial in establishing an indicator system for performance evaluation. This paper adopts the TBL as the basis for indicator selection. By combining the Montreal Process C&I with China's SFM criteria and indicators, a comprehensive indicator system is developed that considers the specific characteristics of forestry enterprises. This system incorporates international standards and national characteristics, considering both macro and micro-level factors while adhering to criteria for indicator selection. With a primary objective of ensuring the sustainability of forest resources, this system encourages the comprehensive development of forestry enterprises regarding their economic, environmental, and societal aspects.

3.1. Indicator Framework

In 1994, John Elkington proposed the Triple Bottom Line (TBL) theory to address the "main concerns of sustainability" [45]. This theory evaluates and analyses enterprises in an integrated manner, using three dimensions - economic, social, and environmental - based on the fundamental requirements and aspects of sustainable development. The same principle applies to SFM as a part of sustainable development. By assuming social responsibility, enterprises can not only actively promote environmental protection and the treatment and remediation of environmental pollution but also improve their social image and attract more consumers and cooperation. It can also attract more investors for economic profit and production development. The TBL can effectively assess the

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impact of the external environment on the internal organisation and balance the environmental, social, and economic aspects from the perspective of a forestry enterprise. It is why many companies are using the TBL to evaluate their performance.

3.2. Selection of Indicator System

The Montreal Process C&I consist of 12 member countries. Together, these countries cover 90% of the world's temperate and boreal forests, 49% of the world's forests, and 49% of the world's roundwood production [46]. The MP C&I have seven dimensions. These dimensions include biodiversity conservation, forest ecosystem productivity, health and vitality of forest ecosystems, soil and water conservation, forest contribution to the global carbon cycle, long-term maintenance and enhancement of multiple benefits from forests, and legal and policy safeguards. The seven dimensions, comprising 67 second-level indicators, cover almost all aspects related to SFM. However, some indicators in the MP C&I may lack monitoring data at the national level, as reported by countries such as the United States and Canada.

According to the MP C&I, many countries have also begun to develop their own standards for SFM. In 2002, China introduced guidelines on forest management, marking the beginning of its focus on SFM. China's vast territory and large population led to significant variations in natural resources and social development across different regions. In order to fully consider this diversity and variations, China has integrated international standards with its unique national conditions to formulate an effective indicator system.

MP C&I has been developed by collaborating with various stakeholders, such as governments, research organisations, NGOs, and private enterprises [47,48]. While MP C&I is implemented at regional and national levels, SFM in forestry enterprises primarily focuses on micro-enterprises. Consequently, certain modifications need to be made to adapt the macro indicators to the specific characteristics of forestry enterprises. This paper aims to establish a performance evaluation indicator system for SFM in forestry enterprises.

3.3. Determination of the Indicator System

The indicator system constructed in this paper takes the three dimensions of economy, society and environment as the first-level indicators; according to the specific indicators of the Montreal Process C&I and China's Criteria and Indicators for SFM in these three dimensions, we select the indicators suitable for the level of forestry enterprises. Then, we add the relevant indicators according to the characteristics of the forestry enterprises to construct the second-level indicators of SFM performance evaluation in forestry enterprises. Meanwhile, the indicators are described with corresponding connotations. The details are shown in Table 1.

Table 1. Performance evaluation indicator system for SFM in forestry enterprises.

Dimension	Indicators system	Indicators description
Environment C1	Rate of increase in area of clear-cutting (c11)	Extensive forests are more resistant to forest shrinkage and protect biodiversity than smaller, more fragmented areas. This indicator is used to analyse the ability of forestry enterprises to conserve biodiversity.
	Rate of increase in afforestation survival (c12)	The ratio of the number of surviving trees to the total number of trees planted per unit area within three years is the rate of increase in afforestation survival. This indicator can reflect the vigour of the forest ecosystem.
	Rate of increase in area of tending trees (c13)	Forest tending refers to measures taken to improve the survival level of forest trees, promote better growth of trees, and increase the productivity of forests. Thus, This indicator reflects efforts to maintain the health of forest ecosystems.

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	Rate of increase in wood production (c14)	Wood production can reflect the production of forestry enterprises in the forestry industry and visualise the production capacity of the forest ecosystem. Therefore, this indicator can effectively reflect the increase extent of forest production capacity.
	Rate of increase in carbon contribution from forest trees (c15)	The carbon sequestration capacity of a forest can be calculated using the forest area. Increasing the area of forest trees can ensure the supply of raw materials for forestry enterprises' forest products and improve the carbon sequestration capacity. Therefore, the increase in afforestation area can reflect the carbon contribution capacity of forest trees.
Society C2	Rate of increase in social welfare assets such as forest recreation and tourism (c21)	Forest biological assets with social responsibilities such as recreation and tourism can well reflect the contribution of forest assets to society. This indicator selects the proportion of public welfare biological assets to total biological assets to evaluate the social welfare input of forestry enterprises.
	Rate of increase in the number of employees in forestry enterprises (c22)	The increase extent of the number of employees in forestry enterprises can reflect the ability of forestry enterprises to provide jobs for society.
	Rate of increase in tax payments (c23)	Enterprises pay taxes and fees by national regulations. Taxes can reflect the ability of forestry enterprises to participate in social responsibility and fulfil tax obligations actively.
	Rate of increase in product quality assurance costs (c24)	As the projected liability of forestry enterprises, the cost of product quality assurance is the cost that forestry enterprises pay customers to ensure product quality, which can reflect the ability of forestry enterprises to bear the responsibility to customers.
Economy C3	Rate of increase in forestry income (c31)	Forestry income is the income earned by forestry enterprises using forest trees. The forestry industry reflects the increasing extent of income of enterprises in the forestry industry.
	Rate of increase in productive biological assets (c32)	Productive biological assets are biological assets held by forestry enterprises for production. The rate of increase can effectively reflect the change in income of forestry enterprises using forest trees.
	Rate of increase in income from forest management (c33)	It reflects the income obtained by forestry enterprises from forest assets and can reflect the ability of forestry enterprises to obtain economic benefits through forest.
	Rate of increase in forestry research and development project inputs（c34）	The proportion of forestry research and development projects reflects the importance that enterprises attach to forestry production and management.

4. MCDM Model For SFM Performance Evaluation in Forestry Enterprises

This paper introduces the MCDM model based on the Triple Bottom Line theory. The MCDM model has been used in forest decision-making to solve various problems, such as harvest scheduling, forest biodiversity conservation, forest sustainability, regional planning, and risk and uncertainty

[26]. In this paper, two methods are used - BWM and VIKOR. Firstly, BWM is used to determine the best and worst indicators, and the remaining indicators are compared with the best and worst indicators, respectively, to determine the weight of each indicator. Afterwards, the improved VIKOR method is used to analyse the situation of the case companies in the past five years and rank them according to the gap with the ideal value. It is convenient to obtain more accurate evaluation results. The specific process of the performance evaluation model of SFM in forestry enterprises is shown in Figure 1.

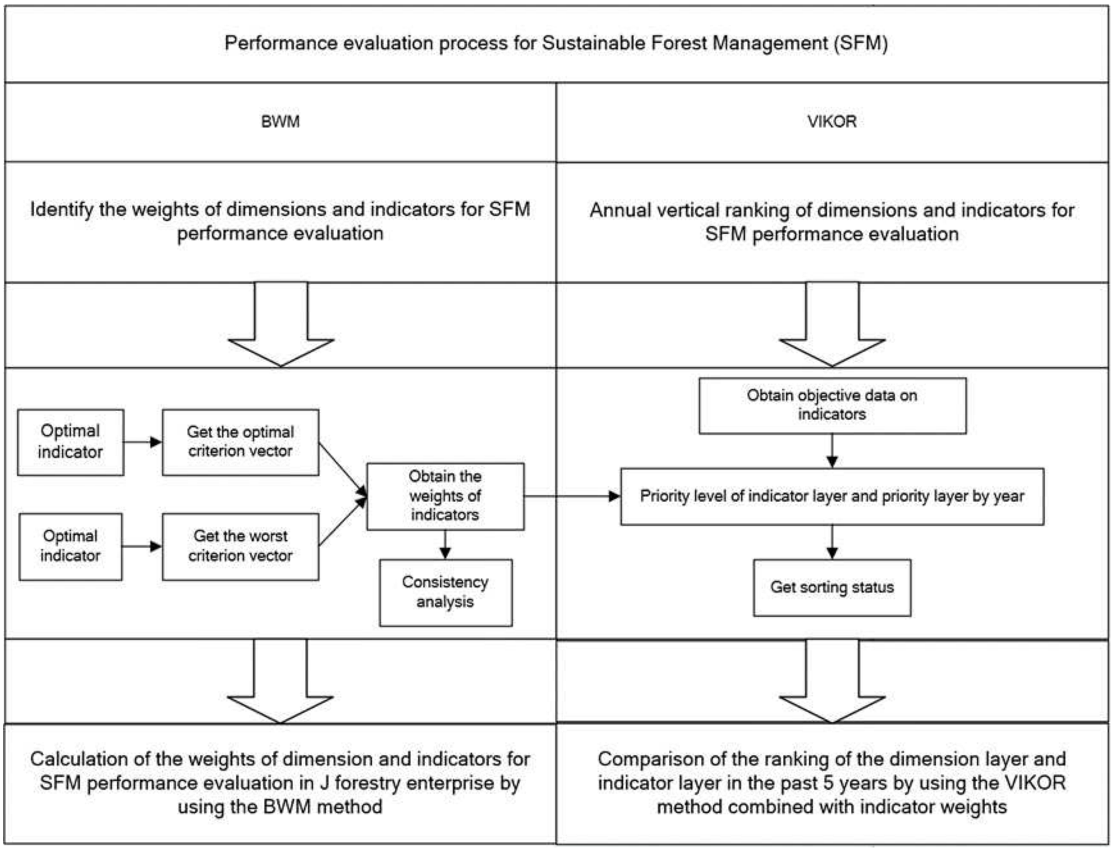

Figure 1. Process of performance evaluation model for SFM.

4.1. Method to Determine the Weight of Performance Evaluation Indicators for SFM in Forestry Enterprises

4.1.1. Best Worst Method for Obtaining Weights

In the past decades, scholars and researchers have proposed several multi-criteria decision-making methods to help decision-makers find the value of criteria and alternatives according to their preferences [49,50]. Best Worst Method (BWM) is an MCDM method recently developed by Rezaei. The best and worst criteria the decision-maker provides are compared with other indicators to obtain two evaluation vectors. BWM method only needs 2n-3 comparisons, where n represents the number of indicators, and the best and worst indicators are compared with other indicators for n-2 times, as well as between the best and the worst indicators [44]. The weights of indicators are obtained by solving a nonlinear [44] or linear model [43]. Since it is a comparison-based method, not only does it require less information, but it is also more accurate to compare more results. In some cases, the result of BWM is multi-optimisation, meaning that the result of solving the problem is a standard set of different weights. This feature can give decision-makers and stakeholders more decision-making options [51–53]. Therefore, in summary, the BWM method has the following advantages: (1) BWM method is more straightforward and uses integers ranging from 1 to 9 for scoring, which reduces the workload of respondents and reduces the number of comparisons; (2) BWM method is suitable for

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both single decision making and group decision making, and has a broader range of applications; (3) The BWM method can be used with many MCDM methods, and the compatibility is more robust.

The specific steps for obtaining subjective weights using the BWM are as follows:

Step 1: Determine the decision-making criteria set and the superiority and inferiority criteria. Construct the indicator set S={s_1, s_2, ……, s_n} according to the decision-making objectives and criteria of the research object, which aims to reflect the performance of various alternatives comprehensively.

Step 2: Distribute questionnaires to obtain scoring vectors. Experts are invited by distributing questionnaires to determine the optimal and the worst two criteria according to the degree of importance. Only the importance of each indicator is considered in the selection, not the actual value. In the 1-9 points range, the importance degree between the best indicator and other indicators is compared by numbers. Where "1" means that the indicator is as important as the best/worst criterion, and "9" means that the indicator is more important than the best/worst criterion.

Two vectors are obtained based on the scoring. One is the vector of preferences of the optimal criterion over all other criteria A_B=(A_{B1}, A_{B2}, ……, A_{Bn}), where a_{Bi} implies the comparative preference of the optimal metric over the metric i and a_{BB}=1. The other is the vector of preferences of all the criteria over the worst metrics $A_w = (A_{1w}, A_{2w}, \dots\dots, A_{nw})^T$, where a_{iW} implies the comparative preference of metric i over the worst metric, and a_{WW}=1.

Step 3: Obtain the optimal indicator weights. Construct the model according to the evaluation objectives and obtain the optimal indicator weights through mathematical planning formula. The formula is as follows:

$$\begin{gathered} \min \quad \max_j \{|w_B - a_{Bi}w_i|, |w_i - a_{iw}w_w|\} \\ s.t. \\ \sum_i w_i = 1 \\ w_i \geq 0, for\ all\ i \end{gathered} \tag{4.1}$$

Where w_B is the weight of A_B; A_i is the criterion vector, and w_i is the actual weight of A_i; w_W is the weight of A_W; a_{Bi} is the importance of A_B to A_i; and a_{iW} is the importance of A_i to A_{iW}. To simplify the computational procedure, equation (4.1) can be converted into a linear equation, i.e. equation (4.2). By solving equation (4.2), the optimal weights $(w_1^*, w_2^*, \cdots, w_n^*)$ can be obtained.

$$\begin{gathered} mink \\ s.t. \\ |w_B - a_{Bi}w_i| \leq k,\ for\ all\ i \\ |w_i - a_{iw}w_w| \leq k,\ for\ all\ i \\ \sum_i w_i = 1 \\ w_i \geq 0, for\ all\ i \end{gathered} \tag{4.2}$$

Step 4: Calculate the consistency ratio. According to the consistency ratio formula, the resulting K value is expressed as K^*, and the consistency ratio CR=$\frac{K^*}{CI}$ is obtained, where CI is the given value. The solved CR value is between 0 and 1, the closer to 0 means better consistency, and when it is 0, it means perfect consistency. The consistency indicators are specified in Table 2.

Table 2. Consistency indicators

a_{BW}	1	2	3	4	5	6	7	8	9
CI (max k^*)	0.00	0.44	1.00	1.63	2.30	3.00	3.74	4.47	5.23

Assume that there are p experts participating in the scoring, and a weighted average of the scoring results is calculated to obtain the final impact matrix:

$$\overline{w}_i^* = \frac{\sum_{a=1}^{p} w_i^a}{p} \tag{4.3}$$

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4.1.2. Descriptive Analysis of Respondents

In this paper, a questionnaire was firstly distributed to relevant scholars and researchers about the importance and influence relationship of the indicators for evaluating the performance of SFM in a Chinese forestry enterprise, 68 questionnaires were distributed, and 68 were finally recovered, which is a recovery rate of 100%. Of these 68 questionnaires received, 51 questionnaires were validly answered, with a valid response rate of 75%. Respondents to this questionnaire had to be experts or scholars involved in SFM performance or forest sustainability research, and were also required to have an in-depth knowledge of the topic. This questionnaire had a small sample of respondents due to the large number of respondents and the time taken to retrieve the questionnaire. The descriptive analyses of the respondents are specified in Table 3.

Table 3. Descriptive analysis of respondents.

Item	Content	Numbers	Ratio
Gender	Female	14	27.45%
	Male	37	72.55%
Age	Over 50 years old	25	49.02%
	40-50 years old	11	21.57%
	30-40 years old	9	17.65%
	Under 30 years old	6	11.76%
Identity	Relevant scholars studying performance evaluation of SFM	31	60.78%
	Personnel working in forestry enterprises and implementing SFM	14	27.45%
	Other	6	11.76%
Years of research/work in SFM	More than 15 years	6	11.76%
	10-15 years	22	43.14%
	5-10 years	13	25.49%
	Less than 5 years	10	19.61%
Educational background	Doctoral degree	28	54.90%
	Master's degree	19	37.25%
	Bachelor's degree	4	7.84%

4.1.3. Determination of Subjective Weights of Indicators

The questionnaire scores for the weights of the SFM performance evaluation indicators in forestry enterprises are 1-9. Considering that there are 51 valid questionnaires, it is necessary to calculate the weights of the data obtained from each questionnaire according to the formula, and the consistency test should be carried out at the same time to obtain the average weight. Table 5 shows the weight results of the dimension layer. Tables 6–8 shows the indicator layer weights and consistency test under the three dimensions respectively. As an example, respondent 1 demonstrates the calculation of weights for the three dimensions using the BWM method. Respondent 1 considers the most important dimension to be the environment (C1) and the least important dimension to be the society (C3), and obtains preferences for the other dimensions based on the identified most important and least important dimensions, resulting in a vector of $\mathrm{C1} = (C_{11}, C_{12}, C_{13}) = (1, 6, 3)$. Correspondingly, obtaining preferences for other dimensions based on the least important dimension produces the vector $\mathrm{C4} = (C_{41}, C_{42}, C_{43}) = (7, 1, 4)$. The details are shown from Table 4 to Table 8.

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Table 4. Dimension layer weights and consistency tests.

Dimension	Average weight	Ksi*	CR
Environment (C1)	0.5911		
Society (C2)	0.2864	0.1475	0.0401
Economy (C3)	0.1225		

Table 5. Indicator weights and consistency tests in the environmental dimension

Dimension	Average weight	Ksi*	CR
Rate of increase in area of clear-cutting (c11)	0.0533		
Rate of increase in afforestation survival (c12)	0.1657		
Rate of increase in area of tending trees (c13)	0.2485	0.0888	0.0296
Rate of increase in wood production (c14)	0.4083		
Rate of increase in carbon contribution from forest trees (c15)	0.1243		

Table 6. Indicator weights and consistency tests in the social dimension

Dimension	Average weight	Ksi*	CR
Rate of increase in social welfare assets such as forest recreation and tourism (c21)	0.0675		
Rate of increase in the number of employees in forestry enterprises (c22)	0.6160	0.1435	0.0321
Rate of increase in tax payments (c23)	0.1899		
Rate of increase in product quality assurance costs (c24)	0.1266		

Table 7. Indicator weights and consistency tests in the economic dimension

Dimension	Average weight	Ksi*	CR
Rate of increase in forestry income (c31)	0.4894		
Rate of increase in productive biological assets (c32)	0.0638		
Rate of increase in income from forest management (c33)	0.1489	0.1944	0.0648
Rate of increase in forestry research and development project inputs（c34）	0.2979		

Table 8. Calculation results of the weights of the evaluation indicator system.

Indicator	Original weight	Overall weight
C1 Environment	0.5911	
Rate of increase in area of clear-cutting (c11)	0.1911	0.1129
Rate of increase in afforestation survival (c12)	0.2310	0.1365

Rate of increase in area of tending trees (c13)	0.2161	0.1277
Rate of increase in wood production (c14)	0.1990	0.1176
Rate of increase in carbon contribution from forest trees (c15)	0.1628	0.0962
C2 Society	0.2864	
Rate of increase in social welfare assets such as forest recreation and tourism (c21)	0.2918	0.0836
Rate of increase in the number of employees in forestry enterprises (c22)	0.4206	0.1205
Rate of increase in tax payments (c23)	0.1198	0.0343
Rate of increase in product quality assurance costs (c24)	0.1677	0.0480
C3 Economy	0.1225	
Rate of increase in forestry income (c31)	0.4959	0.0608
Rate of increase in productive biological assets (c32)	0.1543	0.0189
Rate of increase in income from forest management (c33)	0.1493	0.0183
Rate of increase in forestry research and development project inputs（c34）	0.2004	0.0246

Where *CR*<0.1, it meets the consistency test. By making the indicators as the horizontal axis and the weights as the vertical axis, the comparative importance graphs of the indicators at the dimension level and each indicator level were obtained.

After a series of steps, the weight of each secondary indicator is multiplied by the weight of each primary indicator, and the weight of each indicator of the SFM performance evaluation indicator system in forestry enterprises designed in this paper is finally obtained. The summary table is shown in Table 8 below.

Table 8 shows that for the indicator level, the rate of increase in afforestation survival (c12) has the largest weight of 0.1365, while the rate of increase in income from forest management (c33) has the smallest weight of 0.0183. 0.0183. Looking at the data of the dimension layer, we can find that the largest weight is for the environment (C1), which is 0.5911, and the smallest is for the economy (C3), which is only 0.1225. The weight of the rate of increase in afforestation survival (c12) in the environment dimension is the largest in the indicator layer, so the weight of the related indicator for the environment (C1) is also increased accordingly.

According to the research and analyses of experts and relevant scholars, it can be found that SFM in forestry enterprises should first pay attention to the impact of forestry enterprises on the environment and also pay attention to the health of the forest itself. As part of the ecosystem, forests can contribute to environmental protection and provide an excellent role for the economy, society, environment and governance of forestry enterprises. Therefore, SFM in forestry enterprises should pay more attention to the environmental dimension, not only to make full use of forest resources and improve the production capacity and social contribution of forests but also to rationally develop forest resources and maintain biodiversity, soil and water conservation and the health of the ecosystem itself, to ensure the sustainability of the forests.

4.2. Comprehensive Evaluation Method of SFM Performance in Forestry Enterprises

4.2.1. Theories Related to the VIKOR Method

VIKOR method comes into being to solve the decision problem in the context of multi-dimensional and multi-criteria conflict. The VIKOR method was proposed by Opricovic in 1997, and once proposed, it has attracted wide attention from scholars and has been applied in different fields of research. At its core, the VIKOR method maximises the group benefit value and minimises the individual regret value. It adds the decision-maker's personal preference to it, so the decision-maker can finally accept the resulting compromise solution.

4.2.2. Steps of the VIKOR Method

VIKOR model is constructed for comprehensive multi-criteria evaluation of complex systems. It allows for compromise rankings and alternatives based on assessing "ideal values". Firstly, an ideal solution and a negative ideal solution are determined. VIKOR method calculates the positive and negative ideal solutions for each indicator based on the evaluation of the indicator by the management. It compares the actual values with the calculated results. The indicators with larger difference values need more priority attention and improvement. Finally, according to the evaluation and ranking results, effective improvement strategies are proposed for the sustainable performance of forestry enterprises. The process of VIKOR's method is as follows:

Step 1: Standardise the evaluation values for all alternatives. To avoid the impact of dimensions and attributes on the evaluation, the original value a_{ij} should be standardised. Considering that the indicator system contains indicators of minimum and maximum types, the standardised value x_{ij} is calculated by the formula, which uses the L_p-metric aggregate function, as shown in equation (4.4). This step also adopts Min-max (range) standardisation to standardise the data.

$$L_p = \left\{\sum_{i=1}^{n}\left[\frac{w_i\left(f_i^* - f_{ij}\right)}{\left(f_i^* - f_i^-\right)}\right]^p\right\}^{\frac{1}{p}} \tag{4.4}$$

Where 1≤k≤ ∞, i=1,2,......,n, and n is the total evaluation criteria. f_{ij} represents the evaluated value of alternative O_i at the jth evaluation criterion, f_j^+ denotes the optimal solution, f_j^- denotes the worst solution, and the measure L_p represents the distance between the alternative O_i and the ideal solution.

Step 2: Find negative and positive ideal solutions. Suppose that X^+ and X^- prove positive and negative ideal solutions, respectively, by the following formula:

$$X^+ = (x_i^+) = \left\{\max_j x_{ij} | i \in I_1, \min_j x_{ij} | i \in I_2\right\} \tag{4.5}$$

$$X^- = (x_i^-) = \left\{\min_j x_{ij} | i \in I_1, \max_j x_{ij} | i \in I_2\right\} \tag{4.6}$$

Where I_1 and I_2 represent the maximum and minimum type indicator sets, respectively.

Step 3: Based on the following two equations, the group benefit data S_j and the individual regrets result R_j for j alternatives are obtained. The equations are as follows:

$$S_j = \sum_{i=1}^{n}\frac{w_i\left(x_i^+ - x_{ij}\right)}{x_i^+ - x_i^-} \tag{4.7}$$

$$R_j = \max_i\left(\frac{w_i\left(x_i^+ - x_{ij}\right)}{x_i^+ - x_i^-}\right) \tag{4.8}$$

Step 4: Calculate the compromise ranking result Q_j for each alternative. Q_j is considered to be significant evidence for ranking all alternatives, and the formula is as follows:

$$Q_j = \frac{v(S_j - S^+)}{S^- - S^+} + \frac{(1-v)(R_j - R^+)}{R^- - R^+} \tag{4.9}$$

Among them, $S^- = \max(S_j)$, $S^+ = \min(S_j)$, $R^- = \max(R_j)$, $R^+ = \min(R_j)$. V represents the decision weight coefficient of many criteria. When the coefficient is more significant than 0.5, the decision-making principle of the customisation is to maximise the group effect. When the coefficient is less than 0.5, the principle of the decision-making system is to minimise individual regret. Generally speaking, v is usually 0.5 because it is a "compromise" principle of decision-making, which can effectively meet the maximisation of group effect and minimisation of individual regrets.

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Step 5: According to the above formula, the values of Q, S and R can be obtained, respectively. Firstly, all data's Q, S, and R values are sorted in order from smallest to largest. Q represents the gap value between the indicator and the positive and negative ideal solutions. The closer to the ideal value, the smaller the Q will be. Then compare S_j, R_j, and Q_j to sort all the evaluated alternatives. If the following two conditions are met, then the evaluated alternative with the smallest Q_j value is the best choice.

(1) Acceptable dominance threshold condition, i.e., $Q_i - Q_j \geq 1/(n-1)$, where Q_i and Q_j denote the magnitude of the second and first Q-values sorted according to the Q-values. It is stipulated that the ranking of the first option is determined to be superior to the ranking of the second option only if the difference between two adjacent values of the ranking results in the final Q-value, $Q_i - Q_j$, is not less than a threshold value of 1/(n-1). When more than one option is ranked, the Q value of the first ranked option is compared one by one with the Q value of the second, third, etc., options to see if constraint condition a is satisfied. The constraint condition ensures a high degree of significance among the decision options.

(2) Acceptable decision reliability conditions, i.e., the optimal solution should have the Q value at the top and the S or R-value at the top. Specifically, after the Q value is sorted from small to large (the smaller is the better), the group benefit value S_j in the first place should perform better than the group benefit value S_j in the second place. Either the individual regrets value R_j in the first position must perform better than R_j in the second position, and at least one of the S or R values should also perform better than the second position. When multiple schemes need to be sorted, the scheme in the first place needs to be compared one by one with the other schemes behind it to see whether it satisfies constraint condition b. The constraint condition is to ensure that the decision scheme is more reliable. Only when both of these judgment conditions are satisfied is the Q value considered the most qualified sorting method, i.e., the first-sorted solution is optimal. If only condition a is satisfied, the corresponding objects of Q_i and Q_j are only compromise solutions, and all other solutions that do not meet constraint conditions can be considered optimal. If only condition b is satisfied, then all objects are compromise solutions, and the first and second solutions are optimal.

5. Evaluation and Analysis of Sustainable Forest Management Performance in A Chinese Forestry Enterprise

5.1. Profile of a Chinese Forestry Enterprise

Since its listing in 1996, the Chinese forestry enterprise has effectively used the advantages of its existing scale of forest resources and implemented proactive measures to enhance the efficiency and profitability of its forestry operations. The enterprise has actively engaged in various reforms and optimisations, leveraging its abundant technological, financial, and human resources to accelerate the transition towards a modern, asset-light operation. Additionally, the enterprise possesses several crucial domestic scientific research platforms that provide essential technical support for industrial research and innovation-driven development. As a result, the forestry enterprise has established a prominent position in the industry with a distinct brand influence. Simultaneously, the enterprise actively adheres to the national "dual-carbon" target strategy, promoting sustainable development concepts and seeking the harmonious development of its economic interests with the environment and society. It seizes historic opportunities presented by the rapidly evolving economic environment, continues to drive the industry's transformation and upgrades, and propels the high-quality development of the enterprise.

In addition, enterprises face a complex external environment due to the increasing awareness of environmental protection among people and the national forestry policy that keeps up with the times. The cessation of commercial logging in natural forests has caused a shortage of forest resources, which has become a significant obstacle to the development of the forestry industry. In recent years, China's forestry industry has been striving to eliminate outdated production capacities and improve the species structure. As a result, new technologies and products are constantly emerging, leading to intensified market competition. Therefore, achieving economies of scale and upgrading products and management systems through resource integration has become an urgent issue for the forestry enterprise. Therefore, selecting the forestry enterprise for the performance evaluation of SFM is representative and practical.

5.2. Data Acquisition and Processing

In this part, the data of the Chinese forestry enterprise in the past 5 years (2017-2021) are selected for the longitudinal evaluation of SFM, and the data are mainly from the annual reports, ESG reports of the forestry enterprise and Juchao Information Network, etc. The data are sorted and calculated by manual collation, and then the corresponding processing is carried out by SPSSAU. The raw data of the Chinese forestry enterprise in the past 5 years were standardised, and the processed data is shown in Table 9.

Table 9. Results of data standardisation of the Chinese forestry enterprise by dimension in the past 5 years.

Dimension	Indicator	2017	2018	2019	2020	2021
C1	c11	0.0000	0.9964	0.0000	0.4087	1.0000
	c12	1.0000	0.3356	1.0000	0.0000	0.0000
	c13	0.7034	0.9964	0.6874	0.6587	0.3263
	c14	0.8403	1.0000	0.1783	1.0000	0.3003
	c15	0.1824	0.0000	0.2481	0.1459	0.2766
C2	c21	0.0000	0.9964	0.0000	0.4087	1.0000
	c22	1.0000	0.3356	1.0000	0.0000	0.0000
	c23	0.7034	0.9964	0.6874	0.6587	0.3263
	c24	0.0000	0.2673	1.0000	0.6045	0.9003
C3	c31	0.1824	0.0000	0.2481	0.1459	0.2766
	c32	0.0000	0.9964	0.0000	0.4087	1.0000
	c33	1.0000	0.3356	1.0000	0.0000	0.0000
	c34	0.7034	0.9964	0.6874	0.6587	0.3263

5.3. Evaluation Results and Analysis for Dimension Layer of SFM Performance in a Chinese Forestry Enterprise

Firstly, according to the standardised results of the raw data of the Chinese forestry enterprise for 5 years from 2017-2021 and the weights of each indicator calculated in Table 9, the positive ideal solution (b^+) and the negative ideal solution (b^-) of each indicator in the indicator system are calculated with the help of SPSSAU software, as shown in Table 10.

Table 10. Positive and negative ideal solutions for each indicator of the Chinese forestry enterprise in the last 5 years.

Dimension	Indicator	Positive ideal solution（b^+）	Negative ideal solution（b^-）
C1	c11	-0.772	0.134
	c12	0.357	-0.707
	c13	0.559	-0.616
	c14	0.803	-0.375
	c15	0.863	-0.484
C2	c21	0.480	0.423
	c22	0.008	-0.952
	c23	0.052	-0.875
	c24	0.105	-0.790
C3	c31	0.928	-0.181
	c32	0.195	-0.910

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c33	0.961	0.072
c34	0.633	-0.591

Next, calculate the maximum and minimum values of the group benefit S_j and individual regret value R_j for each evaluation indicator. Group benefit (S) is the weighted distance from each evaluation scheme to the optimal scheme. A smaller S-value means more excellent group benefits. The individual regret value (R) is the weighted distance from each evaluation scheme to the optimal scheme. A smaller R-value means less individual regret. After that, according to the results of group effect value and individual regret value calculate the decision-making indicator Q-value. The smaller the indicator Q-value, the better the scheme, and finally get the ranking. Through the calculation to obtain the group effect value of the optimal value (S^+) is 0.406, the worst value (S^-) is 0.664, the individual regret value of the optimal value (R^+) is 0.084, the worst value (R^-) is 0.137, and then to find the benefit ratio value Q_j (the smaller, the better). The details are shown in Table 11.

Table 11. Optimal and worst values for group effect values and individual regret values.

S+ (Optimal S-value)	S- (Worst S-value)	R+ (Optimal R-value)	R- (Worst R-value)	Lambda
0.406	0.664	0.084	0.137	0.5

Among them, the Lambda value is the risk coefficient value for evaluating pros and cons, between 0 and 1. A larger value implies a preference for risk, while a smaller value implies a more conservative one and generally defaults to 0.5. The following table (Table 12) shows the change of the benefit ratio Q-value (the final solution decision value) when the Lambda value changes (i.e., as the risk preference situation changes).

Table 12. Relationship between Lambda value and benefit ratio Q value.

Value	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
2017	0.8336	0.7503	0.6669	0.5836	0.5002	0.4168	0.3335	0.2501	0.1667	0.0834	0.8336
2018	0.6427	0.6784	0.7142	0.7499	0.7856	0.8214	0.8571	0.8928	0.9285	0.9643	0.6427
2019	0.0000	0.0044	0.0087	0.0131	0.0175	0.0218	0.0262	0.0306	0.0349	0.0393	0.0000
2020	0.6975	0.6851	0.6727	0.6603	0.6478	0.6354	0.6230	0.6106	0.5981	0.5857	0.6975
2021	1.0000	0.9213	0.8426	0.7638	0.6851	0.6064	0.5277	0.4490	0.3703	0.2915	1.0000

Finally, according to the calculated values of R_j, S_j and Q_j, the results of the SFM performance of the forestry enterprise in the past five years were sorted, as shown in Table 13.

Table 13. VIKOR evaluation results and ranking of SFM performance of the Chinese forestry enterprise in the last 5 years.

Year	Group effect value (S)	Individual regret value (R)	Benefit ratio value (Q)	S sort	R sort	Q sort
2017	0.4059	0.1277	0.4168	1	4	2
2018	0.6643	0.1176	0.8214	5	2	5
2019	0.4172	0.0836	0.0218	2	1	1
2020	0.5540	0.1205	0.6354	4	3	4
2021	0.4609	0.1365	0.6064	3	5	3

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Based on the Q_j value shown in Table 13, the dimensional performance of SFM of the forestry enterprise in the past five years can be ranked, i.e. 2019>2017>2021>2022>2018. Because the sample size of the evaluation is 5, the acceptable threshold is 1/ (5-1) = 0.25. According to the two ranking conditions of the VIKOR method, the final ranking result of the forestry enterprise's SFM performance in the past five years is: 2019 =2017 >2021 =2020 =2018. It can be seen that 2019 and 2017 are the best years of SFM performance of the forestry enterprise after compromise. Overall, the Chinese forestry enterprise was more seriously affected by the epidemic in 2020, and there is still a more significant impact in 2021. From the perspective of future development trends, the Chinese forestry enterprise should timely adjust its strategic direction, actively promote the achievement of "30·60" carbon peak and carbon neutrality targets, promote its development and better contribute to society.

5.4. Evaluation Results and Analyses for Indicator Layer of SFM Performance in a Chinese Forestry Enterprise

In order to gain a better understanding of the Chinese forestry enterprise's performance regarding SFM in the last five years, the performance in the environmental, social and economic dimensions of SFM of the forestry enterprise from 2017 to 2021 is evaluated and analysed in detail.

(1) Performance analysis of SFM in the environmental dimension

Based on the values of Q_j shown in Table 14, the performance of the environmental dimension of SFM in the forestry enterprise can be ranked for the last five years as follows: 2019 > 2020 > 2017 > 2018 > 2021. Additionally, based on the two ranking conditions of the VIKOR method, it can be concluded that the environmental dimension of SFM in the forestry enterprise for the last five years is ranked from good to bad as 2019 = 2020 = 2017 > 2018 > 2021. In other words, 2019 is a better year for the environmental dimension of SFM performance in the forestry enterprise, while 2021 ranks relatively poor. The decline in the performance of the environmental dimension of SFM in the forestry enterprise can be analysed by reviewing the company's annual report. With the "double carbon" target taking precedence, there is a growing demand for ecological environmental protection from the public. As a result, there is an increasing requirement for product safety and environmental protection, ultimately impacting the company's industry. This situation poses a significant challenge for the enterprise and its industry. Furthermore, considering that one of the enterprise's main business areas is the production of artificial boards, the business is affected by environmental protection emission requirements and the national logging ban. These factors have led to a shrinking trend in the enterprise's development.

Table 14. VIKOR evaluation results and ranking for the environmental dimension of SFM performance of the Chinese forestry enterprise in the last 5 years.

Year	Group effect value (S)	Individual regret value (R)	Benefit ratio value (Q)	S sort	R sort	Q sort
2017	0.3346	0.2161	0.4229	1	4	3
2018	0.7064	0.1990	0.8217	4	3	4
2019	0.3804	0.1344	0.0600	2	1	1
2020	0.4520	0.1776	0.3774	3	2	2
2021	0.7161	0.2310	1.0000	5	5	5

(2) Performance analysis of SFM in the social dimension

After analysing the value of Q_j presented in Table 15, it is possible to evaluate and rank the performance for the social dimension of SFM in the forestry enterprise over the past five years. The ranking, from best to worst, is 2021 > 2017 > 2019 > 2018 > 2020. This ranking is following the two criteria used in the VIKOR method. Furthermore, a thorough examination of the forestry enterprise's social responsibility report reveals that the company actively participated in key initiatives in 2021. These include the international Verified Carbon Reduction Standard (VCS) forestry carbon sinks pilot project and China's Carbon Currency Exchange (CCER) forest management development project. The

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enterprise plays a pivotal role in contributing towards the "dual carbon" target by engaging in these projects. As a result of these efforts, the enterprise has gained increased visibility and attention in 2021, leading to improved performance in the social dimension.

Table 15. VIKOR evaluation results and ranking for the social dimension of SFM performance of the Chinese forestry enterprise in the last 5 years.

Year	Group effect value (S)	Individual regret value (R)	Benefit ratio value (Q)	S sort	R sort	Q sort
2017	0.3947	0.2107	0.4827	3	2	2
2018	0.5630	0.2527	0.6711	4	3	4
2019	0.3469	0.2919	0.5493	2	4	3
2020	0.7033	0.4207	1.0000	5	5	5
2021	0.0764	0.0335	0.0000	1	1	1

(3) Performance analysis of SFM in the economic dimension

From the values of Q_j shown in Table 16, the performance for the economic dimension of SFM in the forestry enterprise can be ranked in the last five years as follows: 2021 > 2020 > 2019 > 2017 > 2018. According to the ranking conditions of the VIKOR method, it is evident that the performance for the economic dimension of SFM in the forestry enterprise in the recent 5 years is ranked from good to bad as 2021 > 2020 = 2019 = 2017 = 2018. It means that 2021 is the best year for the forestry enterprise in terms of economic performance after considering compromises. From the sorting results, it can be concluded that the forestry enterprise's economic performance in SFM has been continuously improving. Despite the impact of the COVID-19 pandemic, the economic performance of the forestry enterprise has not declined but has improved. The development of the forestry enterprise faces various challenges, including the continuous promotion of new products in the industry, the decrease in raw material quantity and increase in prices, as well as the requirements for environmental protection and emissions and the implementation of national policies on no-timber logging in natural forests. The forestry enterprise has actively responded to these challenges and turned them into opportunities. Specifically, it has made the following efforts: Firstly, it has changed its strategic thinking based on the existing business environment. It plans commercial forests as a business field with a short rotation period while entirely using forest land's natural conditions and production potential. Secondly, it actively capitalises on the carbon sink of corporate forestry by participating in ecological resources rights and interests trading activities, effectively increasing the enterprise's revenue. Thirdly, it promotes forestry conservation, planting, and breeding businesses. Through these measures, the enterprise has further increased comprehensive income from forest land and promoted sustainable development.

Table 16. VIKOR evaluation results and ranking for the economic dimension of SFM performance of the Chinese forestry enterprise in the last 5 years.

Year	Group effect value (S)	Individual regret value (R)	Benefit ratio value (Q)	S sort	R sort	Q sort
2017	0.7754	0.4287	0.9153	5	4	4
2018	0.6981	0.4959	0.9402	3	5	5
2019	0.7587	0.3675	0.8252	4	3	3
2020	0.6968	0.2773	0.6637	2	2	2
2021	0.1289	0.0991	0.0000	1	1	1

5.5. Improvements in the Performance of SFM in a Chinese Forestry Enterprise

5.5.1. Environmental Dimension

The first step is to increase the rate of increase in the area of tending trees, which is an essential indicator of the health and vitality of forest ecosystems. Forest tending refers to various measures taken from planting to maturity to improve the survival rate of forest trees, which can promote better growth of forest trees from various aspects and improve the productivity of forest resources. The Chinese forestry enterprise can only use forest tree resources for subsequent production and sales activities if they ensure the health of forest trees. Therefore, the forestry enterprise should select more vital and adaptable trees and regularly evaluate the health and vitality of trees. To promote an increase in the survival rate of afforestation, the forestry enterprise should implement the following measures: (1) Select high-quality, suitable timber. When investing in tree planting, enterprises should prioritise quality over cost and choose higher-quality seedlings. Although it may increase upfront costs, high-quality forest assets can improve the usage rate of resources and enhance the enterprise's visibility in subsequent business activities. (2) Timely maintenance and inspection. Planting healthy forest trees is only the first step, and regular maintenance is required to prevent a decrease in the survival rate caused by natural or human factors.

The second aspect is the rate of increase in the area of clear-cutting. Compared to small forest areas, extensive forests are more effective in resisting forest decline, reducing environmental degradation, and preserving biodiversity. However, forest companies often exploit forest resources through clear-cutting, which means cutting down all trees in a specific area within a harvesting season. This practice is one of the leading causes of forest fragmentation. Therefore, the forestry enterprise needs to pay attention to the impact of their production and operations on the environment and focus on biodiversity conservation. Potential improvements can be made in the following areas: (1) Consider the future and prioritise long-term interests. It is crucial to focus on current production and operations and consider the damage caused to the environment and forest resources. (2) Enhance the promotion of biodiversity protection and raise public awareness about the importance of forest resource conservation. The forestry enterprise can achieve this through various means, such as producing promotional materials and public service advertisements. These efforts can increase public attention to biodiversity, establish the corporate culture, and enhance the visibility of the enterprise.

5.5.2. Social Dimension

The social dimension of SFM in forestry enterprise is primarily reflected in production, consumption, and employment. They also encompass forest recreation, tourism, and social, cultural, and spiritual values. Among these, the number of employees indicates the company's size and demonstrates the extent to which the company provides employment opportunities. Employment is a significant issue for livelihoods, and enterprises that offer job prospects for the public help alleviate societal employment pressure and expand their scalability. Therefore, the employee growth rate can effectively demonstrate an enterprise's ability to assume social responsibility. The increase in personnel numbers is directly associated with enterprise development. Consequently, the forestry enterprise can attract and provide employment opportunities to the public in various ways, simultaneously creating better development prospects for the enterprise. Specific measures to achieve this include: (1) Strictly adhering to relevant state laws, regulations, departmental rules, and normative documents. It involves formulating and implementing a reasoned salary and performance evaluation system and other enterprise management systems. (2) Enhancing the personnel training system by conducting internal and external training programs. These programs aim to equip managers, technicians, and frontline workers at all levels with job-related knowledge and skills. (3) Improving the promotion mechanism and working environment for staff members. It entails adjusting organisational structure settings, optimising the allocation of human resources, and formulating compensation and performance appraisal plans. These measures effectively address business risks and challenges.

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5.5.3. Economic Dimension

Firstly, the Chinese forestry enterprise should focus on improving the situation of forestry income. The production and sale of forest products is a significant business activity for these enterprises, and the income generated directly impacts their economic profit and development prospects. Economic income provides funds for future enterprise growth and plays a crucial role in fulfilling social responsibilities, protecting the environment, and enhancing management capacity. The forestry enterprise needs to promptly address the status of forestry income, considering that they are involved in producing and selling forest assets. While prioritising the forests' health, it is crucial to enhance production capacity through continuous research and development and by maximising the utilisation of forest resources. Additionally, expanding sales channels and increasing production and sales scope and scale will contribute to the enterprise's higher rate of forestry income growth. The following specific measures can be taken: (1) Improve forestry production efficiency: Boosting production efficiency not only helps reduce costs and increase profitability but also enhances the utilisation of forestry resources, ensuring optimal economic benefits from forest assets. (2) Maintain the health of forest assets: The health of the forest ecosystem is essential for the sustainable use of forest resources. Regularly evaluating the forest condition and promptly addressing any issues will increase the value of forest trees and improve the rate of forestry income growth.

Secondly, the forestry enterprise should also focus on increasing the number of productive biological assets. Productive biological assets primarily include commercial forests and other assets used for production and operational activities. The forestry enterprise needs to prioritise the effective use and management of these productive assets, striving to maximise their usage rate while also paying attention to the condition of forest resources. By enhancing the usage rate of productive biological assets, forestry enterprises can optimise resource allocation, minimise raw material usage, reduce costs, and minimise waste. Moreover, increasing the usage rate of these vital assets contributes to the protection of forest resources and aids in pollution reduction. Therefore, if the forestry enterprise aims to implement SFM practices, it must prioritise expanding its productive biological assets and maximising resource utilisation.

In summary, the Chinese forestry enterprise should focus on developing the economic dimension to improve the usage of forest resources. This includes increasing production and operations in the forestry industry to enhance the rate of increase in forestry income and productive biological assets. Additionally, there is a need to coordinate the co-development of economy, environment and society through governance. The enterprise should actively provide employment opportunities for society while expanding production. It will help improve visibility, gain public recognition, and earn more consumer trust. During the process of production and operation, it is essential to pay attention to the fragmentation of forest trees. Furthermore, it is crucial to preserve the condition of the ecosystem, protect biodiversity, and avoid overexploitation of forest resources due to development. The enterprise should also retain the corresponding assets for sustainable development.

6. Conclusion

This paper provides some contributions to the literature on evaluating the performance of SFM in forestry enterprises. Firstly, most studies on SFM involve the regional and national level, and few focus on the enterprise level. The implementation of SFM in forestry enterprises can reduce the number of indicators and improve the pertinence of indicators, thus improving the feasibility of performance evaluation. Meanwhile, it can enable forestry enterprises to intuitively understand their problems and make corresponding improvements. Secondly, this paper constructs an indicator system based on the TBL principle, which draws on the criteria and indicators of the Montreal Process and the indicator system of SFM in China. The effective integration of the two primary objectives of SFM and the three dimensions of sustainable development of forestry enterprises is conducive to implementing the performance evaluation of SFM in forestry enterprises and can also assist in the development of forestry enterprises. Finally, this paper uses a hybrid MCDM model that combines BWM and VIKOR. The BWM method reduces the workload of respondents' questionnaires and

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improves the validity of the questionnaires. The VIKOR method is used to obtain the SFM performance of forestry enterprises in the past five years (2017-2021), and the ranking is carried out, which is convenient for forestry enterprises to analyse their SFM performance and can also provide reference for later improvement.

There are some limitations in this paper. Firstly, the indicator system in this paper will change with the understanding of the concept of SFM performance of forestry enterprises, and these dimensions and indicator systems need to be continuously optimised and adjusted. Therefore, other critical criteria related to economy, environment and society should be considered in future research. Meanwhile, choosing the indicators suitable for one's enterprise is important. Secondly, the data obtained by the questionnaire is subjective to a certain extent. Although the relevant personnel understand the actual situation of the forestry enterprises in the case, there are still biases in the impact weight and satisfaction scoring process. Therefore, more comprehensive consideration is needed in selecting respondents and questionnaire design. Thirdly, this paper studies and evaluates the SFM ability of forestry enterprises in this case. However, different forestry enterprises have their characteristics, and the indicators may not be targeted enough. There may be a lack of generality. Therefore, the model can be further applied and compared according to the data of forestry enterprises in different regions and countries to make the model more perfect and practical.

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