ISSN 2616-7433 Vol. 6, Issue 11: 21-26, DOI: 10.25236/FSST.2024.061104

Measuring and Evaluating the Efficiency of China's Interprovincial High-Quality Forestry Development under the Concept of "Four Pools"

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Abstract: *High-quality development of forestry is an important part of realizing ecological civilization construction and assisting carbon peak carbon neutral, based on the function of the "four reservoirs" to find out the strategic positioning of China's forestry development, reconstruct its value core and benefit orientation, and realize high-quality development, is a major issue of the times that concerns the strategic overall situation. It is of great practical significance to measure and evaluate the efficiency of high-quality development of forestry through the concept of forestry "four reservoirs". Through the data of 27 provinces and cities in China from 2012 to 2020, the study adopts the super-efficient SBM model and the VIKOR model to measure the efficiency of high-quality development of forestry and evaluate its development preference, opportunity cost and benefit ratio, and the conclusions of the study are as follows: (1) There are obvious regional differences in the efficiency of high-quality development of China's forestry in the period of 2012 to 2020, and the overall situation shows that the efficiency of high-quality development in the south is high and the north is low. (1) There are obvious regional differences in China's forestry high-quality development efficiency from 2012 to 2020, and the overall situation is characterized by regional differences of "high in the south and low in the north". The change in the average value of overall efficiency shows a stable wave-like upward trend. (2) From 2012 to 2020, there will be obvious regional differences in China's forestry high-quality development preference, and the overall situation will be characterized by regional differences of "high in the south and low in the north". (3) There is no obvious regional difference in the opportunity cost of high-quality forestry development in China from 2012 to 2020. (4) From 2012 to 2020, the benefit ratio of China's high quality forestry shows that the benefit ratio of the southern forest area is better than that of the other three major forest areas, and the overall difference in the benefit ratio of the other three major forest areas is not significant.*

Keywords: *"four reservoirs" concept; forestry high-quality development efficiency; development preference; opportunity cost; benefit ratio*

1. Introduction

Forestry development is an indispensable and important component for achieving high-quality development, and a key link in achieving ecological civilization construction and supporting carbon peak and carbon neutrality goals [1,2]. In 2022, China proposed the concept of "four reservoirs" for forestry development: "Forests are reservoirs, money reservoirs, and grain reservoirs, and now we should add a carbon reservoir [3]. The proposal of the "four reservoirs" concept for forestry points out the ultimate goal of high-quality forestry development: conserving local soil and water, developing forestry economy, ensuring food security, and achieving carbon peak and carbon neutrality. However, currently, the development of forestry in China mainly relies on demographic dividends and natural resources. This development model faces many problems such as insufficient resource supply, low return on investment, and insufficient competitiveness [4, 5]. Relying solely on high investment to

ISSN 2616-7433 Vol. 6, Issue 11: 21-26, DOI: 10.25236/FSST.2024.061104

achieve forestry development and growth cannot effectively achieve high-quality development. The core of high-quality development lies in the transformation from quantity to quality. Evaluating forestry development solely based on its growth status is actually contrary to high-quality development. The high-quality development of forestry needs to fully consider the efficiency transformation between forestry development investment and forestry development benefit growth. How to find the strategic positioning of China's forestry development based on the "Four Treasures" function, reconstruct its value core and interest orientation, and achieve high-quality development is a major issue of the times that concerns the overall strategy. Evaluating the efficiency of high-quality forestry development through the concept of "Four Treasures" in forestry is of great practical significance.

At present, research based on the perspective of system dynamics has pointed out that high-quality development of the forestry industry will become a new direction for the future development of forest areas, a new way to transform old and new driving forces, and a new driving force for promoting coordinated economic, social, and ecological development. A path for high-quality development of forestry has also been proposed; Some scholars have also measured the level of high-quality forestry development by constructing an indicator system and analyzed the regional differences in high-quality forestry development [6,7,8]; However, most current research still focuses on theoretical analysis, demonstrating the relationship between forestry development and ecological civilization construction, high-quality development, and dual carbon goals. It clearly points out that improving ecological civilization construction and achieving dual carbon goals must rely on high-quality forestry development, which is an indispensable part of high-quality development [9, 10, 11]. At the same time, based on the current situation of forestry development, a high-quality development path for forestry is proposed, and corresponding countermeasures and suggestions are put forward [12, 13].

In summary, current research has mainly focused on measuring the level of high-quality development in forestry, with relatively little research on measuring the efficiency of high-quality development in forestry. At the same time, the construction of indicator systems is often combined with the five major development concepts, and the application of the "Four Treasures" concept in forestry is relatively rare. Based on this, according to the literature review and the sorting of existing problems in the previous text, the main marginal contribution of the research lies in: (1) filling the research perspective of high-quality forestry development, using the Douglas production function combined with the forestry "four banks" concept to construct an efficiency index system for high-quality forestry development, measuring the efficiency of high-quality forestry development in China's four major forest areas, and assisting in high-quality development. (2) On the basis of the original research on the efficiency calculation of high-quality forestry development, a more in-depth exploration of the research on high-quality forestry development is conducted. The CRITIC weighting method is combined with the VIKOR method to explore the ratio of high-quality forestry benefits, study the overall utilization rate between investment and benefits in each province (city/autonomous region), and further distinguish the development preferences of different regions. The opportunity cost of high-quality development in different forest areas is studied to provide data support and theoretical basis for relevant policy formulation.

2. Calculation and evaluation of forestry development efficiency

2.1 Construction of indicator system

Table 1: Index system of high-quality forestry development efficiency

Target layer	The standard layer	metric	Index unit
Investment index	funding	Total investment completed	Wan Yuan
	human input	Number of employees in the forestry system units at the end of the year	human being
	Construction investment	Afforestation area	hectare
		Forestry workstation	individual
Output indicators	Expect output	Area of soil erosion control	A thousand hectares
		Total output value of the forestry industry	Wan Yuan
		Main forestry food output	ton
	Undesired output	carbon emission	Ten thousand tons

ISSN 2616-7433 Vol. 6, Issue 11: 21-26, DOI: 10.25236/FSST.2024.061104

Based on the above literature analysis and combined with the Douglas production function and the forestry "Four Banks" concept, the following forestry high-quality development efficiency index system is constructed. Among them, the investment indicators are mainly constructed from three major elements: capital investment, manpower investment, and construction investment; The output indicators are based on the concept of the "Four Treasures" in forestry, and are divided into expected output indicators and unexpected output indicators. Among them, the area of soil erosion control corresponds to the "reservoir" function of forestry, the total output value of forestry industry corresponds to the "money bank" function of forestry, the main food production of forestry corresponds to the "grain bank" function, and carbon emissions correspond to the "carbon bank" function. The specific indicator system is detailed in Table 1.

2.2 Evaluation of forestry development efficiency

According to the efficiency evaluation index system shown in Table 1, input and output variables were selected, and the VIKOR method was used to analyze the preferences, opportunity costs, and benefit ratios of high-quality forestry development in 27 provinces and cities in China from 2012 to 2020. The results are detailed in Table 2.

Table 2: Forestry development preference table of the four major forest areas

Region	Province	2012	2013	2014	2015	2016	2017	2018	2019	2020	mean
Northeast forest area	the Heilongjiang River	0.252	0.206	0.186	0.182	0.175	0.180	0.179	0.206	0.232	0.200
	Jilin	0.205	0.178	0.165	0.162	0.159	0.170	0.184	0.228	0.293	0.194
	Nei Monggol	0.798	0.761	0.601	0.562	0.506	0.473	0.483	0.481	0.515	0.575
	Liaoning	0.125	0.105	0.100	0.104	0.126	0.128	0.131	0.137	0.154	0.123
mean		0.345	0.312	0.263	0.253	0.242	0.238	0.245	0.263	0.299	0.273
North forest area	Hebei	0.108	0.098	0.088	0.082	0.081	0.077	0.109	0.103	0.106	0.095
	Henan	0.164	0.144	0.124	0.109	0.100	0.090	0.083	0.089	0.083	0.110
	Shanxi	0.336	0.364	0.325	0.279	0.231	0.218	0.282	0.226	0.243	0.278
	Shandong	0.022	0.014	0.011	0.009	0.007	0.007	0.008	0.008	0.010	0.011
	Qinghai	0.484	0.569	0.585	0.693	0.683	0.842	0.816	1.000	0.976	0.739
	Shaanxi Province	0.167	0.159	0.151	0.125	0.115	0.107	0.108	0.097	0.093	0.125
	Gansu	0.380	0.343	0.306	0.218	0.207	0.220	0.285	0.272	0.315	0.283
	Ningxia	0.252	0.335	0.285	0.289	0.434	0.367	0.349	0.439	0.438	0.354
	Xinjiang	0.198	0.174	0.159	0.139	0.127	0.138	0.130	0.131	0.131	0.148
mean		0.235	0.245	0.226	0.216	0.220	0.230	0.241	0.263	0.266	0.238
Southern forest area	Jiangsu	0.066	0.055	0.048	0.045	0.041	0.037	0.034	0.032	0.030	0.043
	Zhejiang	0.059	0.054	0.050	0.047	0.041	0.035	0.030	0.028	0.029	0.041
	Anhui	0.125	0.108	0.085	0.073	0.062	0.051	0.043	0.039	0.034	0.069
	Fujian	0.060	0.049	0.042	0.038	0.033	0.029	0.020	0.015	0.013	0.033
	Jiangxi	0.124	0.099	0.075	0.061	0.054	0.041	0.036	0.029	0.026	0.060
	Hubei	0.148	0.125	0.107	0.079	0.057	0.048	0.041	0.038	0.043	0.076
	Hainan	0.184	0.183	0.145	0.167	0.161	0.132	0.127	0.246	0.137	0.165
	Hunan	0.107	0.085	0.069	0.058	0.046	0.038	0.032	0.026	0.027	0.054
	Guangxi	0.079	0.055	0.040	0.031	0.026	0.021	0.016	0.006	0.004	0.031
	Guangdong	0.030	0.021	0.014	0.011	0.007	0.005	0.005	0.000	0.004	0.011
	Guizhou	0.359	0.324	0.278	0.235	0.212	0.099	0.071	0.061	0.058	0.189
mean		0.122	0.105	0.087	0.077	0.067	0.049	0.041	0.047	0.037	0.070
Southwest forest area	Yunnan	0.209	0.158	0.138	0.117	0.111	0.092	0.081	0.072	0.060	0.115
	Chongqing	0.332	0.300	0.274	0.262	0.215	0.179	0.160	0.145	0.130	0.222
	Sichuan	0.113	0.097	0.084	0.072	0.060	0.051	0.044	0.039	0.037	0.066
mean		0.218	0.185	0.165	0.150	0.129	0.107	0.095	0.085	0.076	0.134
ensemble average		0.230	0.212	0.185	0.174	0.165	0.156	0.155	0.165	0.169	0.179

As shown in Table 2, there are significant regional differences in China's preference for high-quality forestry development from 2012 to 2020, presenting an overall regional difference characteristic of "high in the south and low in the north", which is consistent with the regional differences in the efficiency of high-quality forestry development. From the average development preference of the four major forest areas, the southern forest area has the strongest development preference, followed by the southwestern forest area, then the northern forest area, and finally the northeastern forest area. From the perspective of development trends, there is not much difference in

ISSN 2616-7433 Vol. 6, Issue 11: 21-26, DOI: 10.25236/FSST.2024.061104

the development preferences of all provinces and cities, and the overall development preferences show a wave like upward trend. From the overall development trend, there is also a wave like upward trend, indicating that the importance of forestry development has been increasing year by year since the proposal of ecological civilization construction at the 18th National Congress of the Communist Party of China in 2012. The results are detailed in Table 3.

Table 3: Opportunity cost table of forestry development in the four major forest areas

Region	Province	2012	2013	2014	2015	2016	2017	2018	2019	2020	mean
Northeast forest area	the Heilongjiang River	0.226	0.225	0.224	0.228	0.227	0.227	0.210	0.219	0.219	0.223
	Jilin	0.170	0.170	0.173	0.175	0.175	0.172	0.167	0.171	0.159	0.170
	Nei Monggol	0.178	0.185	0.180	0.184	0.182	0.183	0.183	0.184	0.090	0.172
	Liaoning	0.282	0.280	0.231	0.237	0.226	0.241	0.225	0.273	0.231	0.247
mean		0.214	0.215	0.202	0.206	0.202	0.206	0.196	0.211	0.175	0.203
North forest area	Hebei	0.276	0.280	0.270	0.275	0.275	0.275	0.186	0.190	0.086	0.235
	Henan	0.574	0.546	0.558	0.551	0.531	0.540	0.455	0.504	0.470	0.525
	Shanxi	0.323	0.328	0.310	0.315	0.303	0.292	0.300	0.309	0.306	0.310
	Shandong	0.428	0.388	0.305	0.313	0.282	0.182	0.194	0.300	0.221	0.290
	Qinghai	0.047	0.047	0.049	0.048	0.048	0.049	0.048	0.046	0.044	0.047
	Shaanxi Province	0.256	0.255	0.227	0.223	0.206	0.197	0.199	0.191	0.171	0.214
	Gansu	0.266	0.265	0.199	0.199	0.184	0.157	0.151	0.131	0.104	0.184
	Ningxia	0.001	0.000	0.001	0.001	0.001	0.001	0.025	0.022	0.022	0.008
	Xinjiang	0.210	0.207	0.204	0.200	0.239	0.243	0.243	0.246	0.248	0.227
mean		0.265	0.257	0.236	0.236	0.230	0.215	0.200	0.216	0.186	0.227
Southern forest area	Jiangsu	0.245	0.217	0.024	0.024	0.030	0.033	0.028	0.060	0.078	0.082
	Zhejiang	0.282	0.285	0.264	0.132	0.084	0.062	0.069	0.133	0.089	0.155
	Anhui	0.208	0.223	0.201	0.200	0.201	0.191	0.177	0.186	0.171	0.195
	Fujian	0.236	0.231	0.227	0.226	0.222	0.216	0.211	0.208	0.204	0.220
	Jiangxi	0.239	0.235	0.232	0.222	0.231	0.225	0.217	0.217	0.189	0.223
	Hubei	0.226	0.226	0.228	0.225	0.228	0.212	0.216	0.208	0.222	0.221
	Hainan	1.000	0.673	0.646	0.502	0.382	0.334	0.308	0.258	0.253	0.484
	Hunan	0.562	0.548	0.542	0.537	0.420	0.400	0.399	0.356	0.287	0.450
	Guangxi	0.288	0.282	0.277	0.274	0.267	0.261	0.266	0.253	0.225	0.266
	Guangdong	0.264	0.257	0.235	0.155	0.174	0.176	0.230	0.240	0.207	0.215
	Guizhou	0.411	0.406	0.373	0.367	0.357	0.353	0.344	0.344	0.348	0.367
mean		0.360	0.326	0.295	0.260	0.236	0.224	0.224	0.224	0.206	0.262
Southwest forest area	Yunnan	0.372	0.374	0.372	0.371	0.363	0.370	0.372	0.369	0.340	0.367
	Chongqing	0.245	0.242	0.039	0.056	0.057	0.078	0.074	0.244	0.210	0.138
	Sichuan	0.366	0.391	0.404	0.392	0.383	0.383	0.409	0.405	0.325	0.384
Mean		0.328	0.336	0.272	0.273	0.267	0.277	0.285	0.339	0.292	0.296
Ensemble average		0.292	0.283	0.251	0.244	0.234	0.230	0.226	0.248	0.215	0.247

As shown in Table 3, there is no significant regional difference in the opportunity cost of high-quality forestry development in China from 2012 to 2020, and the overall difference is not significant. The opportunity cost of high-quality forestry development in the northern region is slightly lower than that in the southern region. The risk of investing in high-quality forestry development in the southern region is greater, that is, investing the same input cost may not bring the expected benefits well, and there is a possibility of efficiency loss. From the overall development opportunity cost evolution of the four major forest areas, it can be seen that they are in a stable downward trend, indicating that the development risks of high-quality forestry development are continuously decreasing, the results are detailed in Table 4.

As shown in Table 4, from 2012 to 2020, the high-quality benefit ratio of China's forestry showed that the benefit ratio of southern forest areas was better than that of the other three major forest areas, and the overall difference in benefit ratios of the other three major forest areas was not significant. And overall, the benefit ratio (Q) of 16 provinces and cities is below 0.2, indicating that about half of the provinces (cities/autonomous regions) can basically achieve the maximization of group benefits and the minimization of individual regrets in environmental governance investment and output, and the investment in high-quality forestry development can be well converted into corresponding benefit outputs. From the trend of change, all provinces have shown a fluctuating upward and downward trend, with an overall wave like downward trend. Without excluding the influence of environmental and

ISSN 2616-7433 Vol. 6, Issue 11: 21-26, DOI: 10.25236/FSST.2024.061104

random factors, there is still room for improvement in the benefit ratio of high-quality forestry development in China's four major forest areas, and there is a need to further improve the input-output ratio and structure.

Table 4: Benefit ratio of high-quality forestry development in the four major forest regions

Region	Province	2012	2013	2014	2015	2016	2017	2018	2019	2020	mean
Northeast forest area	the Heilongjiang River	0.239	0.215	0.205	0.205	0.201	0.203	0.195	0.212	0.226	0.211
	Jilin	0.188	0.174	0.169	0.168	0.167	0.171	0.176	0.199	0.226	0.182
	Nei Monggol	0.488	0.473	0.390	0.373	0.344	0.328	0.333	0.333	0.303	0.374
	Liaoning	0.204	0.192	0.166	0.171	0.176	0.185	0.178	0.205	0.193	0.185
mean		0.279	0.264	0.232	0.229	0.222	0.222	0.220	0.237	0.237	0.238
North forest area	Hebei	0.192	0.189	0.179	0.179	0.178	0.176	0.147	0.147	0.096	0.165
	Henan	0.369	0.345	0.341	0.330	0.315	0.315	0.269	0.297	0.276	0.318
	Shanxi	0.329	0.346	0.317	0.297	0.267	0.255	0.291	0.268	0.274	0.294
	Shandong	0.225	0.201	0.158	0.161	0.145	0.094	0.101	0.154	0.115	0.151
	Qinghai	0.266	0.308	0.317	0.371	0.365	0.445	0.432	0.523	0.510	0.393
	Shaanxi Province	0.212	0.207	0.189	0.174	0.160	0.152	0.154	0.144	0.132	0.169
	Gansu	0.323	0.304	0.253	0.209	0.195	0.188	0.218	0.202	0.210	0.233
	Ningxia	0.126	0.168	0.143	0.145	0.217	0.184	0.187	0.230	0.230	0.181
	Xinjiang	0.204	0.191	0.181	0.170	0.183	0.190	0.187	0.189	0.189	0.187
mean		0.250	0.251	0.231	0.226	0.225	0.222	0.221	0.239	0.226	0.232
Southern forest area	Jiangsu	0.155	0.136	0.036	0.034	0.035	0.035	0.031	0.046	0.054	0.062
	Zhejiang	0.171	0.170	0.157	0.089	0.062	0.049	0.049	0.080	0.059	0.098
	Anhui	0.167	0.165	0.143	0.137	0.131	0.121	0.110	0.112	0.102	0.132
	Fujian	0.148	0.140	0.135	0.132	0.127	0.123	0.115	0.111	0.109	0.127
	Jiangxi	0.182	0.167	0.153	0.142	0.143	0.133	0.126	0.123	0.107	0.142
	Hubei	0.187	0.175	0.168	0.152	0.142	0.130	0.129	0.123	0.132	0.149
	Hainan	0.592	0.428	0.396	0.335	0.271	0.233	0.218	0.252	0.195	0.324
	Hunan	0.334	0.316	0.306	0.297	0.233	0.219	0.216	0.191	0.157	0.252
	Guangxi	0.184	0.169	0.158	0.153	0.147	0.141	0.141	0.130	0.115	0.148
	Guangdong	0.147	0.139	0.124	0.083	0.090	0.090	0.117	0.120	0.105	0.113
	Guizhou	0.385	0.365	0.325	0.301	0.284	0.226	0.208	0.203	0.203	0.278
Mean		0.241	0.215	0.191	0.169	0.152	0.136	0.133	0.136	0.122	0.166
Southwest forest area	Yunnan	0.291	0.266	0.255	0.244	0.237	0.231	0.226	0.221	0.200	0.241
	Chongqing	0.289	0.271	0.156	0.159	0.136	0.128	0.117	0.194	0.170	0.180
	Sichuan	0.240	0.244	0.244	0.232	0.221	0.217	0.227	0.222	0.181	0.225
Mean		0.273	0.260	0.218	0.211	0.198	0.192	0.190	0.212	0.184	0.215
Ensemble average		0.261	0.248	0.218	0.209	0.199	0.193	0.191	0.206	0.192	0.213

4. Conclusions

The study measured the efficiency of high-quality forestry development in China from 2012 to 2020 using the super efficient SBM model and VIKOR method, and evaluated and studied the development preferences, opportunity costs, and benefit ratios of forestry informed development. The following research conclusions were drawn:

(1) There are significant regional differences in the efficiency of high-quality forestry development in China from 2012 to 2020, showing an overall regional difference characteristic of "high in the south and low in the north". The overall efficiency average shows a stable wave like upward trend. Overall, without excluding the influence of environmental and random factors, the high-quality development of forestry in China is in a state of governance that tends towards effective development.

(2) There are significant regional differences in China's preference for high-quality forestry development from 2012 to 2020, showing an overall regional difference characteristic of "high in the south and low in the north", which is consistent with the regional differences in the efficiency of high-quality forestry development.

(3) There is no significant regional difference in the opportunity cost of high-quality forestry development in China from 2012 to 2020, and the overall difference is not significant. The opportunity

ISSN 2616-7433 Vol. 6, Issue 11: 21-26, DOI: 10.25236/FSST.2024.061104

cost of high-quality forestry development in northern regions is slightly lower than that in southern regions.

(4) From 2012 to 2020, the high-quality benefit ratio of China's forestry showed that the benefit ratio of southern forest areas was better than that of the other three major forest areas, and the overall difference in benefit ratios of the other three major forest areas was not significant.

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