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Comparisons of Ecotourism Efficiency and Spatial-temporal Evolution Based on DEA-Malmquist Model: A Case Study of Jiangsu Province in China

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Abstract: *The DEA-Malmquist model was used to measure the ecotourism efficiency of 13 cities in Jiangsu Province from 2010 to 2020, and the spatial and temporal differences were further analysed. The results show that the tourism technical efficiency in Jiangsu Province in China is generally at a high level, and the tourism scale efficiency restricts the improvement of tourism technical efficiency. The unbalanced of the technical progress in tourism between the prefecture-level cities is obvious. Overall, the change of technical progress in tourism has the strongest impact on the total factor productivity index. Therefore, strengthening the inter-regional cooperation of tourism development, training of tourism professionals, improving the structure of tourism industry, optimizing the allocation of tourism production factors, and expanding the scale and agglomeration effect of tourism can improve the efficiency of ecotourism.*

Keywords: *Ecotourism efficiency, DEA-Malmquist model, Differentiation studies, Temporal and spatial evolution*

1. Introduction

With the transformation of China's economy from high-speed growth to high-quality development, green industry and high-quality economic development have become a hot issue in the research of social development. As a green economy industry, the development of ecotourism relies more on the protection level of the ecological environment, and it can bring better economic output without huge resource consumption, which is an important manifestation of the realization of the value of ecological products. Ecotourism plays an increasingly important role in stimulating economic growth and solving employment problems because of its strong correlation, strong driving force, high spillover and transboundary. In the era of popular tourism demand, the booming development of ecotourism reflects people's increasing needs for a better life.

In recent years, scholars have made abundant achievements in the study of tourism efficiency. Some scholars have applied the super-efficiency model in calculation (Lina et al., 2013), which has opened up a feasible path to distinguish the state of efficiency. Based on the super-efficiency model, the eco-efficiency of China's 30 provinces, Yangtze River Delta urban agglomeration and the Yangtze River Economic Belt(Changjiang et al., 2021; Jinhua et al., 2014; Rongrong and Aoxiang, 2021; Zhenqing et al., 2021), and the tourism industry efficiency of China's 30 provinces, coastal provinces (Fang, 2014; Jia et al., 2015; Zhang et al., 2017) are measured.

Some scholars have applied the DEA Malmquist model into the research on the measurement of tourism green productivity (Liu et al., 2019). Matsumoto evaluated the environmental performance of European Union (EU) countries using the data envelopment analysis (DEA) approach and the global Malmquist-Luenberger (ML) index (Matsumoto et al., 2020). Liu used the ML index in data envelopment analysis (DEA) model, measured the green productivity of the tourism in 11 provinces and cities in the Yangtze River Economic Zone YREZ from 2006 to 2015 (Liu et al., 2018). Li used the DEA model and the ML index to measure and calculate tourism GTFP in China between 2007 and 2018, as well as analyze spatio-temporal differences (Li et al., 2020). Based on the DEA-Malmquist index model, Zhong measured the tourism efficiency of 11 cities in the Pearl River Economic Belt from 2011 to 2018 (Xuesi and Linlin, 2021).

However, as far as the overall research is concerned, the research on spatial differentiation of eco-

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tourism efficiency is still relatively broad and lacks in-depth discussion. In view of this, this paper takes 13 prefecture-level cities in Jiangsu province as the research object, measures the ecotourism efficiency of prefecture-level cities in Jiangsu province based on DEA model, in order to better guide the development of tourism in Jiangsu province[1-3].

2. Research methods

2.1 Data envelopment analysis

Charnes proposed the data envelopment analysis method and its model, that is, based on the decision-making unit (DMU) input and output remain unchanged, to evaluate the relative effectiveness of decision-making units (Charnes et al., 1978). There are two traditional DEA models: the CCR model and the BCC model, which respectively express the efficiency of DMU input and output under the condition of constant and variable returns to scale. The government or enterprises can regulate the tourism economic development model and path through the input of capital, labor and other factors, but cannot control and intervene in the output level of tourism. In this paper, BCC model (as shown in formula (1)) is selected, that is, the input-oriented DEA model of the decision-making unit is used to evaluate the efficiency of ecotourism in Jiangsu province. The comprehensive efficiency ranges from 0 to 1, and the closer it is to 1, the more effective DEA is. If there are n decision-making units, m types of input variables (i=1, 2,..., m) and p types of output variables (r=1, 2,..., p), the expression is:

$$\min\left[\theta-\varepsilon\left(\sum_{i=1}^{m}S_i^-+\sum_{i=1}^{p}S_r^+\right)\right]$$

$$s.t\begin{cases}\sum_{j=1}^{n}\lambda_j\cdot x_{ij}+S_i^-=\theta x_0, i=1,2,\cdots,m\\ \sum_{j=1}^{n}\lambda_j y_{rj}-S_r^+=y_0, r=1,2,\cdots,p\\ \lambda_j\geq 0, j=1,2,\cdots,n;\ S_i^-\geq 0, S_r^+\geq 0\end{cases} \quad (1)$$

where x_{ij} and y_{rj} represent the input value and output value of a decision-making unit respectively; λ_j represents the decision variable; S_i^- and S_r^+ represent the relaxation variables of the output and input respectively; θ represents the efficiency value; when θ < 1, DEA is invalid; when θ=1 and the relaxation variable is zero, DEA is effective; when θ=1 and the relaxation variable is not zero, DEA is weakly efficient.

2.2 Malmquist productivity index model

Malmquist index was originally proposed by Malmquist in 1953, and Caves et al. began to apply this index to the measurement of production efficiency changes in 1982 (Caves et al., 1982; Malmquist, 1953). Fare et al. combined a nonparametric linear programming method of this theory with data Envelope analysis (DEA) theory, which made Malmquist index widely used. The Malmquist productivity index model uses time series data to deal with changes in total factor productivity, that is, a model that describes the changes in production efficiency of decision-making units over a period of time.

Based on the DEA-BCC model, the tourism Malmquist productivity index model is used to reflect the intertemporal dynamic changes of tourism input and output in Jiangsu province from 2010 to 2020. The expression of the Malmquist productivity index calculated by the DEA-BCC model from period t to period t+1 is (as shown in Equation (2))

$$MI_{t+1}=\left[\frac{D^{t+1}(x^{t+1},y^{t+1})}{D^{t+1}(x^t,y^t)}\times\frac{D^t(x^{t+1},y^{t+1})}{D^t(x^t,y^t)}\right]^{\frac{1}{2}} \quad (2)$$

Where, MI represents the productivity index, $MI_{t+1}\in(0,\infty)$. If $MI_{t+1}>1$, it represents the efficiency improvement in t+1 period; If $MI_{t+1}=1$, it means that the efficiency of t+1 phase remains unchanged; If $MI_{t+1}<1$, indicates that the efficiency of t+1 stage decreases. D^t and D^{t+1} represent the distance functions based on variable returns to scale in periods t and t+1, respectively. $D^t(x^{t+1},y^{t+1})$ represents the distance between DMU in the t+1 period and the production frontier in the t period, that is, the efficiency of the decision-making unit in the t+1 period is measured by the efficiency of the decision-making unit in the t period. The meaning of other terms in the formula can be analogized[4-8].

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2.3 Variable selection and data sources

Previous research results show that the input-output indexes for measuring eco-tourism efficiency mainly focus on capital, labor and income. In terms of the selection of input variables, tourism as the tertiary industry, the input of capital and labor constitute an important part of tourism input. Therefore, the investment in fixed assets of the whole society, the number of employees in the tertiary industry and per capita green area are selected as input variables for the efficiency evaluation of tourism(Ikram et al., 2021). In the selection of output variables, the variables that can intuitively measure the operating efficiency of tourism are selected. Therefore, total tourism revenue (ten thousand yuan) (Huang et al., 2018) and total tourism population are selected. Total tourism income is the sum of domestic tourism income (ten thousand yuan) and international tourism foreign exchange income (ten thousand dollars). Since the statistical unit of domestic tourism income and international tourism foreign exchange income is inconsistent, the international tourism foreign exchange income and the average exchange rate over the years are multiplied into the tourism income value in ten thousand yuan. The total number of tourists is the sum of the number of domestic tourists and inbound tourists. Thirteen prefecture-level cities in Jiangsu province were taken as the research objects, and the index data were extracted from "Statistical Bulletin of National Economic and Social Development" of each city and "Jiangsu Statistical Yearbook" from 2011 to 2021.

3. Results and Discussion Analysis

3.1 Measurement and comparative analysis of ecotourism efficiency in Jiangsu Province

Based on DEA model, the efficiency of ecotourism in Jiangsu province from 2010 to 2020 are estimated, and the specific measurement results are shown in Tables 1-4. Judging from the comprehensive efficiency values of the cities in Jiangsu province (Table 1), the comprehensive efficiency values of Nanjing, Wuxi, Changzhou, Suzhou and Zhenjiang were all 1.000 during the observation period, indicating that the tourism industry of these cities is active, and the resource allocation of input and output of ecotourism is relatively reasonable. The comprehensive efficiency of tourism industry in Xuzhou reached 1.000 in 2014, and it maintained an effective DEA in the following years, indicating that the advantage effect of ecotourism in Xuzhou began to emerge gradually after the adjustment of investment scale, and continued to play a role in the later period of this observation period, except for a slight decrease in 2020 due to the impact of COVID-19. The comprehensive efficiency of ecotourism in Nantong, Lianyungang, Taizhou, Suqian and Yancheng has not reached the effective DEA, and there is promotion room for improvement in the input-output efficiency of ecotourism[9-10].

Table 1: Comparison of comprehensive efficiency of ecotourism in Jiangsu Province from 2010 to 2020

year	Nanjing	Wuxi	Xuzhou	Changzhou	Suzhou	Nantong	Lianyungang	Huaian	Yancheng	Yangzhou	Zhenjiang	Taizhou	Suqian
2010	1.000	1.000	0.762	1.000	1.000	0.766	0.638	0.651	0.765	1.000	1.000	0.665	0.373
2011	1.000	1.000	0.844	1.000	1.000	0.791	0.641	0.621	0.773	1.000	1.000	0.763	0.409
2012	1.000	1.000	0.829	1.000	1.000	0.771	0.990	0.629	0.682	1.000	1.000	0.796	0.462
2013	1.000	1.000	0.817	1.000	1.000	0.724	1.000	0.626	0.704	1.000	1.000	0.698	0.509
2014	1.000	1.000	1.000	1.000	1.000	0.874	0.712	0.631	0.687	1.000	1.000	0.706	0.607
2015	1.000	1.000	1.000	1.000	1.000	0.875	0.692	0.618	0.684	1.000	1.000	0.723	0.565
2016	1.000	1.000	1.000	1.000	1.000	0.827	0.732	0.626	0.693	1.000	1.000	0.708	0.535
2017	1.000	1.000	1.000	1.000	1.000	0.838	0.782	0.675	0.596	1.000	1.000	0.705	0.552
2018	1.000	1.000	1.000	1.000	1.000	0.859	0.844	0.705	0.668	1.000	1.000	0.680	0.571
2019	1.000	1.000	0.987	1.000	1.000	0.770	0.906	1.000	0.751	1.000	1.000	0.620	0.579
2020	1.000	1.000	0.787	1.000	1.000	0.980	0.948	0.976	0.760	0.940	1.000	0.514	0.759

The comprehensive efficiency value in the DEA model can be further decomposed into the product of scale efficiency and pure technical efficiency, that is, the factors affecting the comprehensive efficiency of ecotourism are evaluated from the aspects of tourism management, technical level, and resource allocation. From the calculation results of the DEA model, it can be seen that the comprehensive efficiency (Table 1), pure technical efficiency (Table 2), and scale efficiency (Table 3) of the five cities of Nanjing, Wuxi, Changzhou, Suzhou, and Zhenjiang are always in an effective state. Scale benefits show constant returns to scale during the observation period, indicating that the existing development model of ecotourism during the observation period is relatively mature, and tourism investment can form tourism economic benefits through tourism output. The comprehensive efficiency of ecotourism in Lianyungang and Suqian is at a low value during the observation period. Through comparison, it is found that the pure technical efficiency of each city is in an effective state in each year, and the low scale

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efficiency is an important factor affecting their comprehensive efficiency. It shows that optimizing the allocation of tourism resources and improving the utilization rate of tourism resources are the breakthrough points to improve the management of ecotourism. The comprehensive efficiency of ecotourism in Huai'an and Yancheng also has not reached the effective state, but the difference from Lianyungang and Suqian is that their pure technical efficiency value and scale efficiency value have not reached the effective state, which together affect their comprehensive efficiency value. It shows that strengthening the management of tourism industry and improving the level of tourism service are important directions for the future development of tourism industry in Huai'an and Yancheng. The pure technical efficiency and scale efficiency of ecotourism in Taizhou remained at an effective level from 2010 to 2015, but dropped by 12.99% and 4.73% respectively in 2020, and the pure technical efficiency dropped even more. It indicates that the original ecotourism resource allocation and management mechanism has been greatly affected by the COVID-19, and relevant tourism policy plans need to be adjusted in time. The pure technical efficiency and scale efficiency of ecotourism in Xuzhou, Yancheng, Lianyungang and Nantong showed fluctuations, indicating that these four cities have not yet formed a mature mechanism in terms of tourism resource utilization, model construction, route development, and so on.

Table 2: Comparison of pure technical efficiency of ecotourism in Jiangsu Province from 2010 to 2020

year	Nanjing	Wuxi	Xuzhou	Changzhou	Suzhou	Nantong	Lianyungang	Huaian	Yancheng	Yang Hou	Zhenjiang	Taizhou	Suqian
2010	1.000	1.000	1.000	1.000	1.000	0.951	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2011	1.000	1.000	1.000	1.000	1.000	0.946	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2012	1.000	1.000	1.000	1.000	1.000	0.936	1.000	1.000	0.997	1.000	1.000	1.000	1.000
2013	1.000	1.000	0.984	1.000	1.000	0.903	1.000	0.964	1.000	1.000	1.000	1.000	1.000
2014	1.000	1.000	1.000	1.000	1.000	0.951	1.000	0.951	0.944	1.000	1.000	1.000	1.000
2015	1.000	1.000	1.000	1.000	1.000	0.927	1.000	0.923	0.929	1.000	1.000	1.000	1.000
2016	1.000	1.000	1.000	1.000	1.000	0.885	1.000	0.950	0.917	1.000	1.000	0.999	1.000
2017	1.000	1.000	1.000	1.000	1.000	0.895	1.000	0.980	0.869	1.000	1.000	0.996	1.000
2018	1.000	1.000	1.000	1.000	1.000	0.908	1.000	1.000	0.869	1.000	1.000	0.974	1.000
2019	1.000	1.000	1.000	1.000	1.000	0.963	1.000	1.000	0.979	1.000	1.000	0.947	1.000
2020	1.000	1.000	0.997	1.000	1.000	1.000	1.000	1.000	0.941	0.970	1.000	0.824	1.000

Table 3: Comparison of scale efficiency of ecotourism in Jiangsu Province from 2010 to 2020

year	Nanjing	Wuxi	Xuzhou	Changzhou	Suzhou	Nantong	Lianyungang	Huaian	Yancheng	Yangzhou	Zhenjiang	Taizhou	Suqian
2010	1.000	1.000	0.762	1.000	1.000	0.805	0.638	0.651	0.765	1.000	1.000	0.665	0.373
2011	1.000	1.000	0.844	1.000	1.000	0.836	0.641	0.621	0.773	1.000	1.000	0.763	0.409
2012	1.000	1.000	0.829	1.000	1.000	0.823	0.990	0.629	0.684	1.000	1.000	0.796	0.462
2013	1.000	1.000	0.830	1.000	1.000	0.802	1.000	0.650	0.704	1.000	1.000	0.698	0.509
2014	1.000	1.000	1.000	1.000	1.000	0.919	0.712	0.664	0.728	1.000	1.000	0.706	0.607
2015	1.000	1.000	1.000	1.000	1.000	0.944	0.692	0.670	0.736	1.000	1.000	0.723	0.565
2016	1.000	1.000	1.000	1.000	1.000	0.934	0.732	0.659	0.755	1.000	1.000	0.708	0.535
2017	1.000	1.000	1.000	1.000	1.000	0.936	0.782	0.688	0.686	1.000	1.000	0.708	0.552
2018	1.000	1.000	1.000	1.000	1.000	0.946	0.844	0.705	0.769	1.000	1.000	0.698	0.571
2019	1.000	1.000	0.987	1.000	1.000	0.800	0.906	1.000	0.767	1.000	1.000	0.655	0.579
2020	1.000	1.000	0.789	1.000	1.000	0.980	0.948	0.976	0.808	0.968	1.000	0.624	0.759

In general, among the 13 cities in Jiangsu province, the average value of the comprehensive efficiency of ecotourism in southern Jiangsu is higher, while the average value of the comprehensive efficiency in northern Jiangsu is lower. The results show that the ecotourism resource endowment of southern Jiangsu has a strong attraction, and the input factors of the ecotourism industry can accelerate the transformation of the economic benefits of the tourism industry, and provide a sustainable power to stimulate the improvement of the provincial ecotourism efficiency and boost the integrated development of tourism.

3.2 Temporal and spatial evolution analysis of ecotourism efficiency in Jiangsu Province

In order to have a deeper understanding of the utilization efficiency of ecotourism resources, this paper brings the panel data of Jiangsu province at the municipal level from 2010 to 2020 into Malmquist index model. DEAP 2.1 software was used to analyse the total factor productivity index (TFP) of ecotourism and its decomposition dynamic efficiency of Malmquist index model in 13 municipalities of Jiangsu province. The specific calculation results are shown in Table 4.

The average annual growth rate of the total factor productivity index (TFPCH) in the study region reached 2.0%, but there was some fluctuation in this growth during 2010-2019, and the average annual growth rate of the total factor productivity index reached 6.0%. This shows that the total factor

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productivity of ecotourism in 13 cities of Jiangsu province is on the rise as a whole, while the total factor productivity index bottomed out at 0.719 in 2019-2020, mainly due to the impact of COVID-19, which delayed the overall development of ecotourism. In terms of the technology progress index (TECHCH), the technology progress index was above 1.0 in most years except 2019-2020, with an annual growth rate of 0.8%.

By subdividing the technical efficiency index (EFFCH), it can be seen that the pure technical efficiency index (PECH) showed a slight decline, with the minimum value of 0.987 appearing in 2019-2020. The average annual growth rate of the scale efficiency index (SECH) was 1.3%, and the minimum value appeared in 2014-2015 and 2015-2016, both of which were 0.998. It shows that the development of pure technical efficiency in the study area is in a stable and slightly declining trend, while the level of scale efficiency is in a slow process of improvement.

To sum up, the research area has a good scale of tourism development, which is the main reason for promoting the continuous development of ecotourism. However, the problems existing in tourism management in various cities have always restricted the further improvement of the development efficiency of ecotourism in the research area[11-15].

Table 4: Malmquist production index and dynamic efficiency of decomposition in Jiangsu Province from 2010 to 2020

YEAR	EFFCH	TECHCH	PECH	SECH	TFPCH
2010-2011	1.026	1.025	1.000	1.026	1.051
2011-2012	1.035	1.061	0.999	1.036	1.097
2012-2013	0.994	1.056	0.993	1.001	1.050
2013-2014	1.017	1.052	1.000	1.017	1.070
2014-2015	0.992	1.078	0.995	0.998	1.070
2015-2016	0.996	1.069	0.998	0.998	1.065
2016-2017	1.003	1.039	0.999	1.004	1.041
2017-2018	1.020	1.030	1.001	1.019	1.050
2018-2019	1.026	1.022	1.012	1.014	1.049
2019-2020	1.005	0.715	0.987	1.019	0.719
mean	1.011	1.008	0.998	1.013	1.020

Observing the average total factor productivity of ecotourism in Jiangsu Province based on the Malmquist index model (Figure 1), it can be found that the growth rate of total factor productivity (TFPCH) of Nantong city was 22.7% during the observation period, which was at the highest level among the 13 cities, mainly due to the balanced improvement of technological progress (TECHCH) and scale efficiency (SECH).

The mean of total factor productivity of 13 cities in Jiangsu province was higher than 1.000, the mean of total factor productivity of Xuzhou, Nantong, Huai'an and Yancheng was higher than the overall average level of 1.020, and the mean of total factor productivity of other cities was lower than the overall average level. Because the southern of Jiangsu is a relatively mature area of economic development scale and ecotourism, the growth rate of total factor productivity is at a low level. In terms of scale efficiency, the average scale efficiency of 13 cities in Jiangsu province was 1.013, and only two cities in Yangzhou and Taizhou had scale efficiency lower than 1.000, indicating that the overall scale of ecotourism in Jiangsu province showed a slight increase[16-18].

In order to further reveal the spatial distribution of the mean level of total factor productivity of eco-tourism in Jiangsu province from 2010 to 2020 and the degree of mutual influence among cities, the total factor productivity can be divided into five levels according to the equal interval method, namely, low-value area, second-low area, medium-value area, second-high area and high-value area (Figure 2).

According to the analysis results, the total factor productivity of Nantong, Huai'an, Xuzhou and Yancheng is at a high level from 2010 to 2020. These cities are rich in ecological resources, tourist attractions and characteristic agricultural products, and there is a large space for the improvement of ecological tourism. The total factor productivity of Yangzhou, Zhenjiang is at a relatively low level. Due to the small economic size of these cities, the input-output of tourism and the low efficiency of technological progress affect the total factor production efficiency. The total factor productivity indicators of other cities are all above 1.000, which are in a stable state. Among them, cities such as Nanjing, Suzhou, Wuxi, and Changzhou have relatively significant growth in technological progress efficiency, which have also improved urban total factor productivity to a certain extent. The economic development of these cities is highly comprehensive, the tourism infrastructure is complete, management level and policy optimization are relatively complete, and the tourism industry has a high degree of

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integration, and a relatively mature tourism development model has been formed.

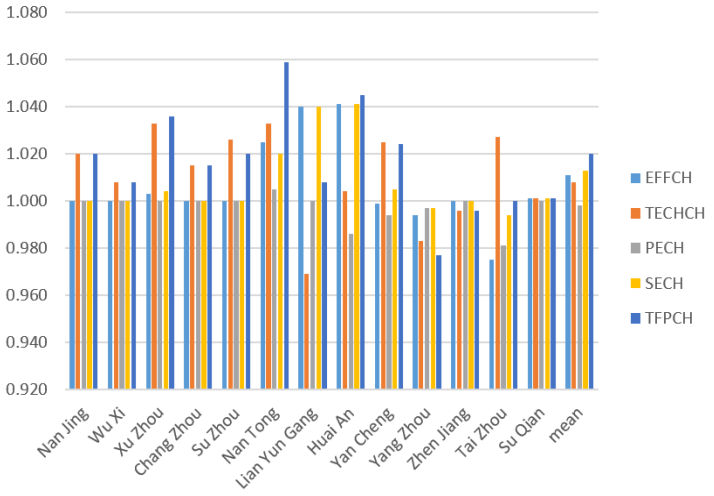

Figure 1: Malmquist Productivity Index of ecotourism in Jiangsu Province from 2010 to 2020

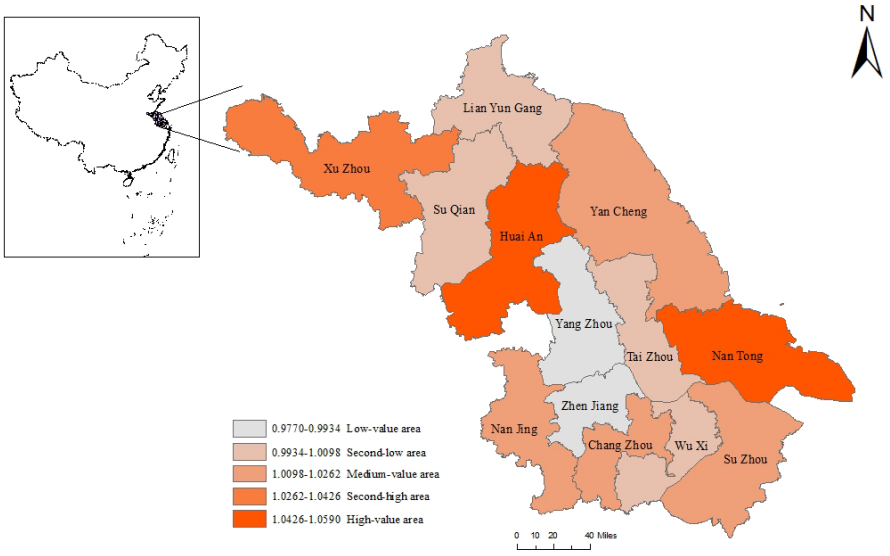

Figure 2: The spatial distribution of mean total factor productivity of ecotourism in Jiangsu Province from 2010 to 2020

4. Conclusions

In this work, based on the comparison and spatial-temporal analysis of ecotourism efficiency in Jiangsu province from 2010 to 2021, the following conclusions are drawn:

1) There is still a certain potential for improvement in the comprehensive efficiency of ecotourism in Jiangsu. On the fact that ecotourism efficiency has spatial spillover and spatial correlation effect, Jiangsu province should strengthen the free flow of tourism production factors between cities, break the administrative boundary, strengthen the cooperation of regional tourism development, and promote the rational allocation of technology, talent and other important resources.

2) There is a large gap in the technical progress of ecotourism among cities in Jiangsu province. It is necessary to constantly improve the management level of tourism industry in cities with less technical progress, and optimize the management mode, so as to improve the comprehensive efficiency of tourism.

3) In the process of tourism development, it is necessary to continuously innovate, strengthen the application of new technologies, and strive to improve the efficiency of tourism. At the same time, according to the different characteristics of tourism development in different cities, the tourism industry structure should be improved, the allocation of tourism production factors should be optimized, and the

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agglomeration effect of tourism scale should be expanded, so as to improve the scale efficiency of tourism.

4) This study considers factors that affect tourism efficiency, such as scale efficiency, economic development level and regional conditions. DEA model is a quantitative analysis model based on input-output data. However, some factors that are difficult to quantify, such as government policies and emergencies, are also one of the important factors affecting the efficiency of tourism. In addition, EDA model lacks prediction of future development. Therefore, it is necessary to continue to explore ways to improve the efficiency of ecotourism and establish a more reasonable evaluation index system for ecotourism efficiency.

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