



ISSN: 2723-9535

Available online at www.HighTechJournal.org

HighTech and Innovation Journal

Vol. 6, No. 3, September, 2025



Research on Carbon Emission Estimation of Rural Tourist Attractions Through Digital Management

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Received 05 February 2025; Revised 03 July 2025; Accepted 11 July 2025; Published 01 September 2025

Abstract

Objectives: This study aims to estimate the carbon emissions of scenic spots in rural tourism using digital management technology. **Methods:** The Dashahe National Wetland Park, located along the old course of the Yellow River in Feng County, Jiangsu Province, was taken as a case for analysis. During the analysis process, the carbon emission, carbon absorption, and net carbon emission amount of the park during 2018-2023 were estimated. The correlation between different types of land area and the carbon absorption amount was analyzed. **Findings:** The carbon emission of the wetland park increased annually, but the carbon absorption amount also showed a consistent upward trend, resulting in relatively stable net carbon emissions over the study period. Moreover, the area of wetlands, water bodies, and grasslands exhibited a significant positive correlation with the carbon absorption amount, whereas the correlation between the area of cultivated lands and garden lands and the carbon absorption amount was insignificant. **Innovation:** This research applied digital management technology to precisely collect data related to carbon emissions within the scenic spot, enabling a more reliable estimation of its carbon footprint.

Keywords: Rural Tourism; Digital Management; Carbon Emission; Estimation.

1. Introduction

Developing rural tourism is aimed at reducing the dependence of rural areas on a single agricultural economy, thereby effectively enhancing the overall economic benefits of rural areas and improving the living standards [1-3]. As the problem of global climate change becomes more serious, the management and control of carbon emissions have become the focus of global attention [4-6]. Therefore, estimating and managing carbon emissions in rural tourist attractions is particularly critical [7-9]. As an emerging management method, digital management provides a new perspective and solution for carbon emission estimation of scenic spots in rural tourism. Ke et al. [10] estimated the carbon dioxide emission reduction cost of China's industrial sector during 2006-2010. They made a post-estimate of the carbon emission reduction cost saved by carbon emission rights exchange among different industries in 30 provinces in China during the same period.

Zhu et al. [11] described the carbon finance coefficient model based on factors related to carbon finance and established a carbon emission cost estimation model based on factors affecting carbon emission cost and carbon finance coefficient. They found that the carbon emission cost correlates prevention cost, cost control, carbon content, industrial added value, carbon finance index, etc. Liu et al. [12] proposed an innovative real-time carbon emission estimation

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 <http://dx.doi.org/10.28991/HIJ-2025-06-03-017>

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framework for industrial parks based on a non-invasive load monitoring algorithm and a data-driven method based on reliable real-time electric meter data. Experimental results verified the effectiveness of this method. Chen et al. [13] proposed a two-stage trained non-intrusive load monitoring network, low root-mean-square error (RMSE)-ResNeSt, in order to reduce the error of real-time carbon emission monitoring results. The experimental results showed that LRMSE-ResNeSt successfully reduced the RMSE of real-time carbon estimation by an average of 14.94%. Based on the energy consumption data of Chinese ports from 2010 to 2019, Fan et al. [14] used the stochastic impacts by regression on population, affluence, and technology model to study the carbon emission trends of Chinese ports under different scenarios and analyzed the possibility of the peak of carbon dioxide emissions in Chinese ports.

Ma et al. [15] proposed a method for estimating carbon emissions of urban traffic vehicles based on sparse trajectory data. The above-mentioned related studies have all conducted relevant research and analysis on carbon emissions. Some analyzed the connection between carbon emissions and finance, some focused on estimating carbon emissions, and some placed the research focus on the changes of carbon emissions in the time dimension. This article focuses on estimating the carbon emissions of tourist attractions using digital management technology, thereby analyzing the relevant factors affecting the carbon emissions of tourist attractions. This paper briefly introduces the digital management and carbon emission estimation methods of tourist attractions and then makes a case analysis of the Dashahe National Wetland Park located on the old course of the Yellow River in Feng County, Jiangsu Province, China. The structure of this paper is Abstract - Introduction - Estimation Method of Carbon Emissions in Tourist Scenic Spots - Case Analysis - Discussion - Conclusion. The contribution of this paper lies in revealing the carbon emission characteristics of Dashahhe National Wetland Park in recent years and providing data support and practical reference for the implementation of precise digital carbon management in scenic spots in the future.

2. Carbon Emission Estimation of Tourism Scenic Spots Under Digital Management

For the statistics of the number of people in the scene area, in the digital management [16], cameras inside and at the entrance and exit of the scenic spot will be used to record the flow of people in the scenic spot; for the statistics of the dietary status, the area providing catering services will upload the business data actively to record the dietary consumption in the scenic area, which can be used to calculate indirect carbon emissions. In rural tourism scenic spots, digital management can effectively improve the management efficiency of the scenic spots, and the data recorded in the management process can provide effective support for the estimation of carbon emissions in the scenic spots [17].

Before estimating the carbon emissions of tourist attractions, it is necessary to understand the structure of carbon sources that lead to carbon emissions. As shown in Table 1, the carbon sources of tourist attractions are divided into those related to tourism development and those related to surrounding rural activities [9, 18-21].

Table 1. Carbon source structure of tourist attractions

Tourism Carbon Source	Carbon sources related to tourism development	Carbon sourced from transportation
		Carbon sourced from accommodations
		Carbon sourced from diets
		Carbon sourced from shopping and entertainment
		Carbon sourced from scenic spot management
		Carbon sourced from waste disposal
	Carbon sources related to rural activities around the scenic spot	Land use change
		Carbon sourced from resident activities

The field measurement method [10] is one of the methods for estimating carbon emissions. This method requires a large number of monitoring facilities, and it is difficult to monitor some indirect carbon emissions. Moreover, rural tourist attractions are usually open environments. Generally, there will be a significant change in carbon dioxide concentration only at the emission outlet, and in areas far away from the outlet, the atmospheric carbon dioxide concentration will quickly decrease to normal levels. The model method is generally used for carbon emission estimation at the national level. The construction of the model is difficult, and moreover improper model construction will result in a significant deviation in estimation. The carbon emission coefficient method is the most widely used carbon emission estimation method at present. The method has a mature estimation formula and emission coefficient, so it only requires collecting the corresponding data and inputting them to obtain the estimation results [11]. Therefore, this paper uses the carbon emission coefficient method to estimate the carbon emission amount of tourist attractions, and the estimation formula can be summarized as:

$$Y = a \times X \quad (1)$$

Where Y is the carbon emission amount, a is the carbon emission factor, and X is the amount of resources corresponding to the carbon emission coefficient.

The corresponding carbon emission coefficient is selected according to the carbon source structure shown in Table 1, and the resource data corresponding to the coefficient is obtained through the digital management platform.

3. Case Analysis

3.1. Subject for Analysis

The author once studied for a doctoral degree at Nanjing Normal University in Jiangsu Province, which is close to the Dashasha National Wetland Park. Therefore, a case analysis was conducted using the Dashahe National Wetland Park located on the old course of the Yellow River in Feng County, Jiangsu Province, China. The wetland park's aerial view is shown in Figure 1. The Dashahe National Wetland Park is located in Erba Village, Dashahe Town, Feng County, Xuzhou, Jiangsu Province, China. It is the first station of the old course of the Yellow River entering Jiangsu Province and also the source of Baili Dasha River. The wetland park starts from Provincial Road 254 in the east, reaches the Fengdang border in the west, extends to the old course of the Yellow River in the south, and reaches the Dashasha River in the north. It is 8.1 kilometers long and has a total area of 381 hectares.

The wetland park has various types of wetlands, including permanent river wetlands, with an area of approximately 214.91 hectares, accounting for 73.53% of the entire wetland park area. In the park, the biodiversity is rich, providing habitats for numerous animals and plants. At the same time, it is also an important stopover point for many migratory birds. The wetland park is divided into five functional areas: ecological conservation area, restoration and reconstruction area, publicity and exhibition area, rational utilization area, and management service area. Each area has its specific function. For example, the ecological conservation area is mainly dedicated to protecting the wetland ecosystem, and the publicity and exhibition area has a wetland culture exhibition hall, aiming to popularize environmental protection knowledge and enhance the public's environmental protection awareness. The structure and area of the whole wetland park are shown in Table 2.

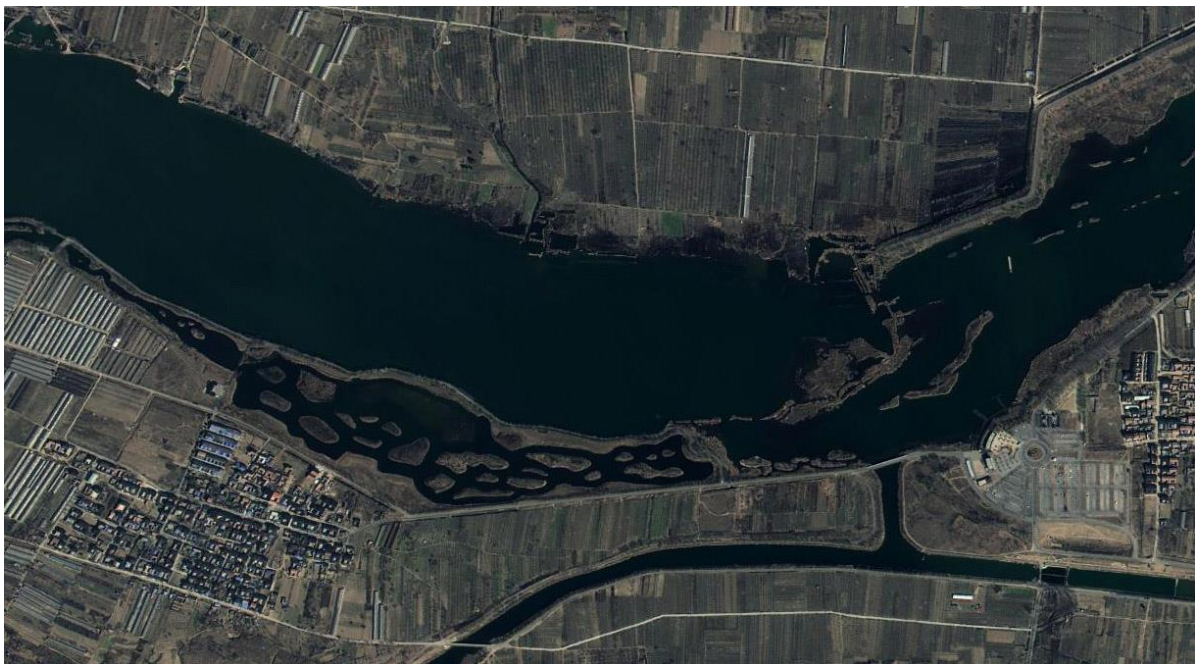


Figure 1. An aerial view of the Dashahe National Wetland Park

Table 2. The proportion of each area in the wetland park

Area type	Area/hectare	Percentage/%
Ecological conservation area	156.9	41.2
Restoration and reconstruction area	139.2	36.5
Teaching and display area	43.1	11.4
Rational utilization area	28.3	7.4
Management service area	13.5	3.5

3.2. Analysis Method

The basic flow of the analysis method is presented in Figure 2. Considering the accessible approaches to the carbon emission-related data of the scenic areas within the wetland park, this paper adopted the carbon emission coefficient method to estimate the carbon emissions. The carbon emission coefficient of various carbon sources was estimated through the relevant parameters presented in the China Energy Statistical Yearbook [22]. The types of carbon sources in the wetland park were preliminarily screened before the formal estimation to reduce the calculation difficulty. Among the eight carbon sources shown in Figure 1, the carbon sourced from accommodations was ignored in the estimation because few places around the wetland park can provide accommodations, and their specifications are small. The wetland park is mainly open to the public in the form of ecological tourism, and there are no large-scale shopping and entertainment facilities inside. Only small souvenir sales points are available, which will not generate much electricity consumption. Therefore, the carbon sourced from shopping activities was also ignored. In addition, the number of local residents is relatively small compared with the flow of tourists, so the carbon sourced from resident activities was ignored.

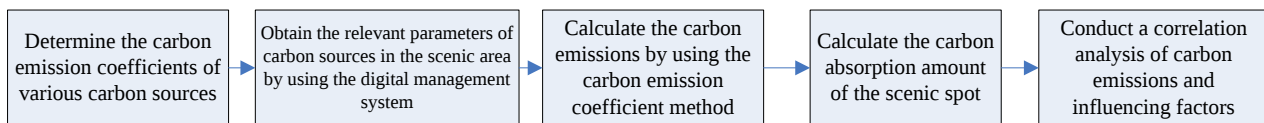


Figure 2. The basic flow of the analysis method

Through the field investigation of the wetland park scenic spot and the collection of relevant data from the digital management platform of the park administration department, the relevant parameters of carbon emission estimation obtained are shown in Table 3. Among them, the transport-sourced carbon is mainly brought by private cars and long-distance buses. The former is usually used in family travel, and the latter is usually used in tour group travel, both of which are the main sources of tourists in the park. The dietary-sourced carbon is mainly brought by the small and medium restaurants around the wetland park, and the carbon emission per capita is calculated using data collected through field investigation and the management department's platform. Carbon emissions from scenic area management primarily originate from the tourist reception center, and the carbon emission is obtained by converting the annual electricity consumption of the reception center. The carbon of waste disposal mainly refers to the carbon emission brought by the disposal of wastes generated in the scenic area [22].

Table 3. Carbon emission related parameters

Carbon source		Carbon emission-related parameter				
Transport	Primary means of transportation	Carbon emission factor $kg\ Co_2 / km$	Number of passengers/person	Average distance travelled /km	Carbon emissions per capita / $kg\ Co_2$	
	Private car	0.25	3	55	4.58	
	Long-distance passenger bus	0.071	25		0.156	
Diet	Main restaurant specifications	Average number of tables/table	Single table specification/people	Average seating rate / %	Operating carbon footprint / kg	Per capita carbon emission / $kg\ Co_2$
	Small restaurants	6	4	85	37.28	1.83
	Medium-sized restaurants	20	10	85	458.03	2.69
Scenic spot management	Main management facilities	Quantity / n	Number of staff/person	Carbon emission converted from annual electricity consumption/ kg	Annual working time/day	Carbon emissions per capita $kg\ Co_2$
	Visitor reception center	3	15	11577.89	300	2.57
Waste disposal	Main waste producing area	Amount of waste produced / t	Carbon emission converted from waste disposal / t	Carbon emission per capita $kg\ Co_2$		
	Scenic spot	5684.56	4117.64	0.82		

If only the carbon emission generated by the carbon sources in the scenic spot is calculated, the relevant parameters in Table 3 can be used, but in the actual situation, there is not only carbon emission but also carbon absorption. In the terrestrial ecosystem, vegetation can fix CO_2 through photosynthesis, and the water area can also absorb carbon dioxide. Therefore, the carbon absorption effect of different land types in the wetland park should be taken into account when calculating net carbon emissions (Table 4).

Table 4. Parameters related to carbon absorption

Land type	Carbon absorption rate coefficient ($t/hm^2 \cdot a$)
Grassland	3.49
Cultivated land	0.48
Garden	4.636
Water	5.424
Wetland	7.547

The carbon emission coefficient method was adopted to analyze the carbon emission amount of the wetland park from 2018 to 2023. The relevant parameters required are as described above. The area of different land types and the flow of visitors in the scenic spot were obtained from the digital management platform of the wetland park management department. In addition, a correlation analysis was performed on land type area and carbon absorption amount [23, 24], and the correlation was significant when the P value was less than 0.05.

3.3. Analysis Results

The carbon emission coefficient method was adopted to estimate the annual carbon emission amount of the Dashahe Wetland Park from 2018 to 2023 (Figure 3). With the passing of years, the total carbon emission amount in the park gradually increased. Among the carbon sources that produced carbon emissions, the carbon emissions from transportation and diet accounted for the largest proportion, while the carbon emissions from scenic area management and waste disposal accounted for a relatively small proportion. The carbon emissions from transportation and diet also increased with the increase in years.

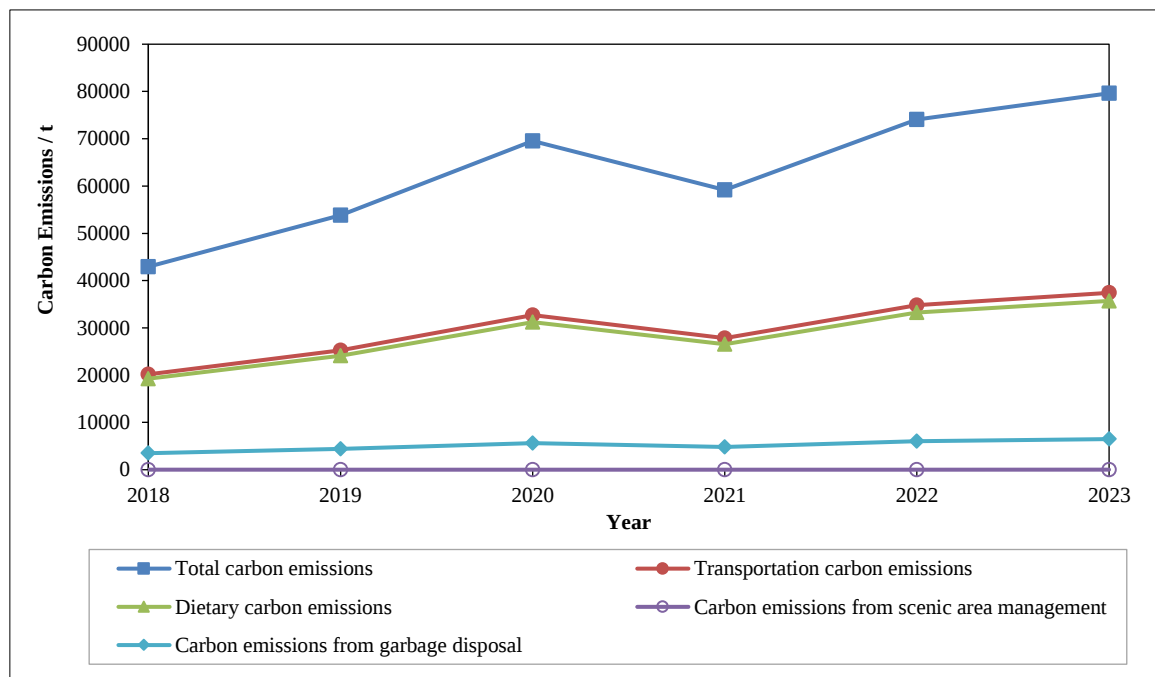


Figure 3. Annual carbon emissions of the Dashahe Wetland Park from 2018 to 2023

Although the park produces a lot of carbon emissions, the wetland environment of the park has the ability to absorb carbon dioxide. Therefore, the net carbon emission may be relatively small, which will not cause damage to the ecological environment. The total annual carbon emission, annual carbon absorption, and net carbon emission of the park from 2018 to 2023 are presented in Figure 4. Although the total carbon emission increased year by year, the carbon absorption amount of the wetland park also increased year by year. As a result, the annual net carbon emission of the park only increased slightly and remained at a relatively low level on the whole, ensuring that the tourism industry of the wetland park did not cause damage to the ecological environment.

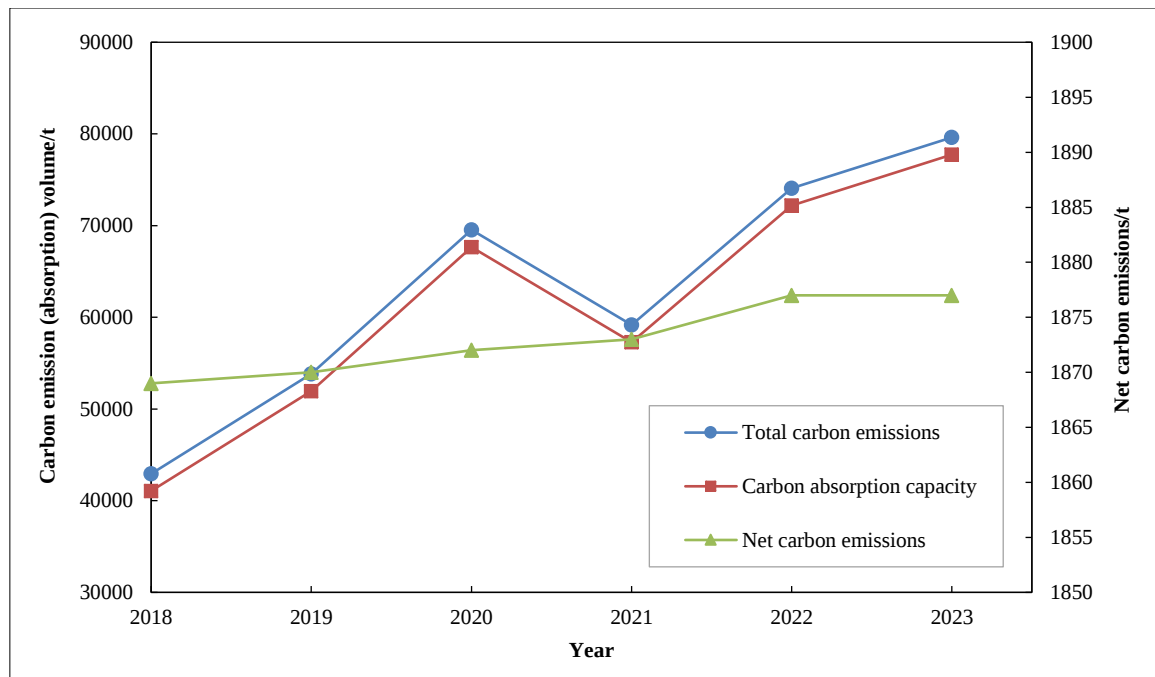


Figure 4. The total annual carbon emission amount, annual carbon absorption amount, and net carbon emission amount of the park from 2018 to 2023

By understanding the carbon absorption capacity of different types of land within the wetland park, adjustments can be made to the land management strategies to enhance the carbon absorption ability of the wetland park. The correlation analysis results of the area of different land types and the amount of carbon absorption are shown in Table 5. The area of cultivated lands and gardens had no significant correlation with the amount of carbon absorption in the wetland park, while the area of grasslands, water bodies, and wetlands was significantly positively correlated with the amount of carbon absorption.

Table 5. Results of correlation analysis of the area of different land types and carbon absorption amount in the park

Land type	Correlation coefficient	P value
Grassland	1.21	0.014
Cultivated land	0.32	0.321
Garden	0.97	0.414
Water	2.98	0.031
Wetland	3.69	0.012

4. Discussion

The main purpose of developing rural tourism is to decrease the dependence of rural areas on a single agricultural economy, thereby effectively enhancing the overall economic benefits of rural areas and improving the living standards. However, while tourism raises incomes, it also increases carbon emissions. For example, a scenic spot will attract a large number of tourists, and there must be a large number of vehicles in the way of tourists to the scenic spot, which will directly produce carbon emissions. The electricity, gas, and other energy consumed by restaurants around the scenic spot in the operation process will also produce carbon emissions. Without some control, although the tourism economy can develop, it will also have a negative impact on the ecological environment. Therefore, estimating the carbon emissions within the scenic area is essential for effective management.

In addition, with the progress of information technology, digital management is gradually applied to the management of scenic spots. A digital management platform can be built for scenic spots to collect relevant data, such as the flow of tourists, the types and quantities of transportation tools used by tourists, the operating conditions of restaurants in scenic spots, and the distribution of land types in scenic spots. The data collected by the digital management method is combined with the carbon emission coefficient method to estimate the carbon emission of the scenic spot. This paper used the carbon emission coefficient approach to estimate the carbon emission of the Dashasha National Wetland Park, calculated the carbon absorption amount in the park, and analyzed the correlation between the area of different land types in the wetland park and the carbon absorption amount.

With the passage of 2018 to 2023, the total carbon emission of the wetland park increased year by year, and the carbon emission from transportation and diet accounted for the majority of the total carbon emission. The reason is that the carbon emission from transportation is caused by transportation used by tourists, while the carbon emission from diets is caused by the service provided by the restaurants around the scenic spot. The operation of management facilities causes the carbon emission in the management of scenic spots. However, the number of people required for management is far less than that of tourists. The carbon emissions from waste disposal require only a small number of people to transport waste. Moreover, waste disposal is usually unified by specialized companies. Therefore, the amount of carbon emissions is relatively small.

From 2018 to 2023, although the net carbon emission amount of the wetland park increased, the overall change was not much. The reason is that the carbon absorption amount of the wetland park was also gradually increasing due to the restoration of the wetland ecosystem in the ecological conservation area and the restoration area in the park, which indicates that the wetland park effectively protects and restores the ecosystem.

The correlation analysis results of different types of land area and carbon absorption amount showed that the area of wetlands, water bodies, and grasslands in the park had a significant positive correlation with the carbon absorption amount, while the area of cultivated lands and gardens had no significant correlation with it. As the wetland park is a measure to protect the wetland ecosystem, and its opening to the outside world is an additional service, the wetland, water, and grassland area in the wetland ecosystem is the largest, leading to a more significant impact on the carbon absorption amount.

The contribution of this paper lies in revealing the carbon emission characteristics of the Dashasha National Wetland Park in recent years and providing data support and practical reference for the implementation of precise digital carbon management in the future scenic spot. The limitation of this paper is that it only analyzed the Dashasha National Wetland Park. The results obtained from the analysis have certain particularities, and the analysis results cannot be effectively extended to other tourist scenic spots. Therefore, future research will expand the analysis scope to make the results as universal as possible.

5. Conclusion

This study first briefly introduces the application of digital management in modern scenic spots and discusses the basic methods and key indicators for estimating carbon emissions in tourist scenic spots. Subsequently, taking the Dashasha National Wetland Park along the old course of the Yellow River as the research subject, a case analysis was carried out. The carbon emission amount, carbon absorption amount, and net carbon emissions of the wetland park from 2018 to 2023 were systematically estimated. At the same time, the relationship between the area of different land types and the carbon absorption capacity within the park was also analyzed in depth. From 2018 to 2023, the total carbon emission amount of the wetland park showed an increasing trend year by year. Among them, tourist transportation and food consumption were the main sources of carbon emissions, accounting for a large proportion of the total. Although the net carbon emission amount increased slightly in these six years, the overall fluctuation was small, indicating that the carbon absorption capacity of the park offset the increase in carbon emissions to a certain extent. In terms of land types, there was a significant positive correlation between the area of wetlands, water bodies, and grasslands and the carbon absorption capacity. In contrast, the area changes of cultivated land and garden had no obvious impact on carbon absorption.

The contribution of this paper lies in revealing the carbon emission characteristics of the Dashasha National Wetland Park in recent years and providing data support and practical reference for the implementation of precise digital carbon management in the future scenic spot. The limitation of this paper is that it only analyzed the Dashasha National Wetland Park. The results obtained from the analysis have certain particularities, and the analysis results cannot be effectively extended to other tourist scenic spots. Therefore, future research will expand the analysis scope to make the results as universal as possible.

6. Declarations

6.1. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6.2. Funding

The author received no financial support for the research, authorship, and/or publication of this article.

6.3. Institutional Review Board Statement

Not applicable.

6.4. Informed Consent Statement

Not applicable.

6.5. Declaration of Competing Interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

7. References

- [1] Wang, S., Wang, X., Han, Y., Wang, X., Jiang, H., & Zhang, Z. (2023). Ship Fuel and Carbon Emission Estimation Utilizing Artificial Neural Network and Data Fusion Techniques. *Journal of Software Engineering and Applications*, 16(3), 51–72. doi:10.4236/jsea.2023.163004.
- [2] Redowan, M., Phinn, S., Roelfsema, C., & Aziz, A. A. (2021). Satellite estimation of emission factors and emissions of biomass-carbon due to deforestation and forest degradation in Bangladesh for a REDD+ program. *Journal of Applied Remote Sensing*, 15(01), 1–28. doi:10.1117/1.jrs.15.014510.
- [3] Liu, J., Liu, G., Zhao, H., Zhao, J., Qiu, J., & Dong, Z. Y. (2024). Real-time industrial carbon emission estimation with deep learning-based device recognition and incomplete smart meter data. *Engineering Applications of Artificial Intelligence*, 127(Part B), 107272. doi:10.1016/j.engappai.2023.107272.
- [4] Zhang, C., He, W., & Hao, R. (2016). Comprehensive estimation of the financial risk of iron and steel enterprise-based on carbon emission reduction. *Journal of Scientific & Industrial Research*, 75(3), 143–149.
- [5] Lee, K., Ko, J., & Jung, S. (2024). Quantifying uncertainty in carbon emission estimation: Metrics and methodologies. *Journal of Cleaner Production*, 452, 1–10. doi:10.1016/j.jclepro.2024.142141.
- [6] Zhang, L., Bai, Y., Zhang, R., Ma, Y., & Shen, C. (2024). Carbon emission characteristics and carbon reduction analysis of employee travel-taking a research institute as an example. *Energy Informatics*, 7(1), 1–19. doi:10.1186/s42162-024-00407-2.
- [7] Guo, H., Awasthi, M. K., Xue, Z., Zhao, Z., Liu, Q., & He, L. (2023). Innovative carbon emission estimation strategy for biomass materials using near-infrared (NIR) spectrum. *Fuel*, 332, 126020. doi:10.1016/j.fuel.2022.126020.
- [8] Tsanov, E., Valchev, D., Ribarova, I., & Dimova, G. (2024). Quality of Harvested Rainwater from a Green and a Bitumen Roof in an Air Polluted Region. *Civil Engineering Journal*, 10(5), 1589–1605. doi:10.28991/CEJ-2024-010-05-015.
- [9] Ghosh, S., Dinda, S., Chatterjee, N. D., Dutta, S., & Bera, D. (2022). Spatial-explicit carbon emission-sequestration balance estimation and evaluation of emission susceptible zones in an Eastern Himalayan city using Pressure-Sensitivity-Resilience framework: An approach towards achieving low carbon cities. *Journal of Cleaner Production*, 336, 130417. doi:10.1016/j.jclepro.2022.130417.
- [10] Wang, K., Xian, Y., Zhang, J., Li, Y., & Che, L. (2016). Potential carbon emission abatement cost recovery from carbon emission trading in China: An estimation of industry sector. *Journal of Modelling in Management*, 11(3), 842–854. doi:10.1108/JM2-03-2016-0027.
- [11] Zhu, N. P., Zhao, Q., & Shen, Y. (2014). Cost Analysis of Carbon Emission Based on Carbon Finance. *Advanced Materials Research*, 1065–1069, 3030–3034. doi:10.4028/www.scientific.net/amr.1065-1069.3030.
- [12] Liu, J., Liu, G., Zhao, H., Zhao, J., Qiu, J., & Dong, Z. Y. (2023). A real-time carbon emission estimation framework for industrial parks with non-intrusive load monitoring. *Sustainable Energy Technologies and Assessments*, 60(December), 1–12. doi:10.1016/j.seta.2023.103482.
- [13] Chen, F., Gao, Y., Wang, J., Wu, M., Zhang, W., & Teng, F. (2024). Real-Time Carbon Emission Estimation for Industrial Users With Low RMSE Based on NILM and Evolutionary Algorithm. *IEEE Transactions on Instrumentation and Measurement*, 73, 1–11. doi:10.1109/TIM.2024.3476562.
- [14] Fan, S., & Lu, Z. (2022). Research on the Peak Carbon Dioxide Emission Strategy of Chinese Port Based on Carbon Emission Estimation. *Frontiers in Environmental Science*, 9, 1–6. doi:10.3389/fenvs.2021.789970.
- [15] Ma, W., Liu, Y., Alimo, P. K., & Wang, L. (2024). Vehicle carbon emission estimation for urban traffic based on sparse trajectory data. *International Journal of Transportation Science and Technology*, 16, 222–233. doi:10.1016/j.ijtst.2024.01.010.
- [16] Hung, L. Q., & Thao, V. T. P. (2021). Building Land Cover Objects Following the IPCC Guidelines for Carbon Emission Estimation. Case Study in the Central Highlands of Vietnam. *Sustainability in Environment*, 6(1), 45. doi:10.22158/se.v6n1p45.
- [17] Yushardi, Romadhona, S., Fitria, F. L., Mandala, M., & Kristianta. (2020). Carbon emission estimation model and correlation with green open space in Jember City Area. *IOP Conference Series: Earth and Environmental Science*, 485(1), 1–9. doi:10.1088/1755-1315/485/1/012116.

- [18] Manongga, D., Rahardja, U., Sembiring, I., Aini, Q., & Wahab, A. (2024). Improving the Air Quality Monitoring Framework Using Artificial Intelligence for Environmentally Conscious Development. *HighTech and Innovation Journal*, 5(3), 794–813. doi:10.28991/HIJ-2024-05-03-017.
- [19] Mohiuddin, O., Asumadu-Sarkodie, S., & Obaidullah, M. (2016). The relationship between carbon dioxide emissions, energy consumption, and GDP: A recent evidence from Pakistan. *Cogent Engineering*, 3(1), 1–16. doi:10.1080/23311916.2016.1210491.
- [20] Shahzad, S. J. H., Kumar, R. R., Zakaria, M., & Hurr, M. (2017). Carbon emission, energy consumption, trade openness and financial development in Pakistan: A revisit. *Renewable and Sustainable Energy Reviews*, 70(4), 185–192. doi:10.1016/j.rser.2016.11.042.
- [21] Wang, C., Wang, F., Zhang, X., Yang, Y., Su, Y., Ye, Y., & Zhang, H. (2017). Examining the driving factors of energy related carbon emissions using the extended STIRPAT model based on IPAT identity in Xinjiang. *Renewable and Sustainable Energy Reviews*, 67, 51–61. doi:10.1016/j.rser.2016.09.006.
- [22] National Bureau of Statistics of China (2013) *China Statistics Yearbook 2013*. China Statistics Press, Beijing, China.
- [23] Li, B., Liu, X., & Li, Z. (2015). Using the STIRPAT model to explore the factors driving regional CO₂ emissions: a case of Tianjin, China. *Natural Hazards*, 76(3), 1667–1685. doi:10.1007/s11069-014-1574-9.
- [24] Wang, Y., Ge, X., Liu, J., & Ding, Z. (2016). Study and analysis of energy consumption and energy-related carbon emission of industrial in Tianjin, China. *Energy Strategy Reviews*, 10, 18–28. doi:10.1016/j.esr.2016.04.002.