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Carbon emission measurement and water treatment in Poyang Lake eco-economic zone in the context of energy saving and emission reduction in tourism

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ABSTRACT

For the purpose of responding positively to the global low carbonization process, energy conservation and emission control in the tourism has become a new tourism development boom. Based on the analysis of the influencing elements of tourism carbon release measurement and so on, the scope of tourism carbon emitting system is defined as the amount of carbon dioxide produced by the energy consumption of tourism & transport, tourism lodging, tourism events and tourism catering, and the model of tourism carbon emitting measurement of these four sectors is constructed; and the tourism carbon emitting of Poyang Lake Ecological Economic Zone is measured, and the measurement results are analyzed from various sectors of tourism and various regions. The result is that the carbon emitting of tourism in this study area in 2012 is 2.016 million tons, and the carbon emitting of tourism transportation, tourism lodging, tourism activities and tourism catering are 1.146 million tons, 626,800 tons, 133,700 tons and 95,100 tons, respectively; the carbon emitting of four cities, namely Jiujiang, Nanchang, Ji'an and Shangrao, reaches the carbon emitting of tourism in this area. The carbon emitting of four cities, namely Jiujiang, Nanchang, Ji'an and Shangrao, reaches 65.15% of the overall carbon emitting of tourism in this area, which has great potential of energy conservation and emission control.

Keywords: Tourism; Energy conservation and emission control; Poyang Lake; Carbon emission; Measurement

1. Introduction

In the last few years, the increasing incidence of extreme global disaster events caused by climate issues had an extremely negative impact on ecosystems and there is an urgent need to build a low carbide economy to promote sustainable development and preserve the common home of mankind [1]. "Low carbon economy" refers to an economic development approach that aims to minimize greenhouse gas emissions, especially the effective control of carbon dioxide, a major greenhouse gas. With the intensification of global climate change, countries around the world have begun to attach importance to low-carbon economy. In recent years, it is widely believed internationally that due to the impact of human factors, the concentration of greenhouse gases in the global atmosphere is becoming higher and higher, and the global climate is gradually changing. In the foreseeable future, global warming caused by rising concentrations of greenhouse gases will have a negative impact on people's lives. Therefore, developing a low-carbon economy is an important way to prevent global warming and achieve sustainable development. As an industry with a high correlation with the natural environment, tourism needs to be supported by climatic conditions and

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in the meantime should focus on energy conservation and emission control to reduce its carbon footprint on the climate and environment and to promote its own sustainable development [2]. In today's world, due to climate change, the tourism industry has been impacted unprecedentedly, and scenic spots around the world are also on the brink of extinction. Currently, various international tourism organizations have paid great attention to this issue. Through a series of meetings and related reports, they have expressed their concern about the development of tourism and environmental change. In order to protect the environment, reducing carbon emissions, and developing low-carbon tourism have become an international trend. Based on the analysis of the carbon emitting characteristics of the tourism, it is possible to measure its carbon emitting, analyse its potential for energy conservation and emission control, and propose countermeasures for the development of energy conservation and emission control in the tourism in order to contribute to its sustainable development [3].

2. Related work

With the increasing effects of global climate change, energy conservation and emission control has become a major trend in the development of all industries. Many learned men have conducted many research for the purpose of building a low carbide economy and reducing carbon emitting, and a lot of research results have been achieved.

Rico et al. [4], for the purpose of evaluating the carbon footprint of tourism activities in Barcelona, analysed elements such as the key figures of its carbon emitting and considered transport and accommodation, the results showed that transport had the largest carbon emitting at 95.6%, that is, transport has a great potential for carbon reduction. Vourdoubas [5], for the purpose of measuring the carbon emitting of tourism in Crete, Greece, proposed various in order to explore the relationship between tourism growth and environmental level, Tian et al. [6] used tourism economic data from 1995–2015 to investigate the specific situation between tourism economic growth and carbon emitting, and the results showed that tourism development can contribute to the reduction of carbon emitting. For the purpose of investigating the relationship between tourism and environmental pollution in three low- and middle-income Southeast Asian economies, Ahmad et al. [7] used carbon emitting as an indicator of environmental pollution and conducted robustness tests to show that the environmental impact of tourism varies across environmental policies and that the development of appropriate policies can facilitate the reduction of carbon emitting from tourism. Wang et al. [8] to investigate the relationship between domestic tourism demand, carbon emitting and economic growth in China, they used a bottom-up approach to measure carbon emitting from tourism and conducted causality tests. The results of the calculations showed that carbon emitting from domestic tourism in China have been on an increasing trend and that there is a biphasic causal relationship between economic growth, carbon emitting and tourism revenue, providing guidance for the development of policies using.

Akadiri et al. [9] In order to study the relationship between tourism growth and carbon emitting in tourism island countries, a mixed average grouping method based on a dynamic panel was used to test the environmental Kuznets curve for 16 tourism island countries from 1995–2016, and the results showed that the square of tourism and income has a negative impact on carbon emitting, and that there is a bi-directional causal and uni-directional causal relationship between globalisation, tourism and carbon emitting, respectively. Debbage and Debbage [10] used aviation data to calculate the carbon emitting of direct and connecting routes between a number of different international tourist destinations in order to investigate whether direct tourism can reduce carbon emissions from air travel, and the result is that the carbon emitting from direct routes are significantly less than those from transit routes. Li and Yao [11] studied the possibility of synergies between the supply and demand sides of energy in China. The results show that cutting coal capacity and carbon tax can promote energy conservation and emission control, and that coal capacity and carbon tax have synergistic effects, so the two can be combined. Wu and Li [12] developed a time-varying model of national and provincial carbon emissions for the case that changing the economic growth pattern of the marine industry is conducive to the achievement of low-carbon development goals, and the result is that the carbon emitting gradually increase over the study time, the carbon emitting of the marine industry all show a power function relationship with time, and the carbon emitting of different provinces or cities have different time-dependent models. Zhang [13] addressed the situation that industry has a greater impact on energy conservation and emission control, and the results of the calculations show that Northwest China has the greatest potential for reduction of CO_2 releases and that there is spatial agglomeration in the industrial sectors of the 30 provinces.

Zhang and Lin [14] studied the cement industry based on the perspective of factor substitution in view of the more serious issues of energy conservation and emission control in the cement industry and used a log. The results of the study show that the cement industry becomes more dependent on capital inputs, so the use of natural gas can be increased in the process of cement production to promote energy conservation and emission control. Hu et al. [15] established a carbon footprint optimization model for reducing carbon emitting in the field of cold chain logistics to benefit energy conservation and emission control, introducing distance coefficients etc. into the model. The simulation results show that it can facilitate the improvement of response measures and contribute to the achievement of energy conservation and emission control. In order to study whether the emission trading system can achieve energy conservation and emission reduction in developing countries, Hu et al. [16] used a difference model to test the impact of carbon emissions trading on energy conservation and emission reduction based on panel data of China's provincial double-digit industrial industries from 2005 to 2015. The results show that compared to non-pilot areas, CO_2 ETS has reduced energy consumption and CO_2 emissions of regulated industries in pilot areas by 22.8% and 15.5%, respectively. Overall, CO_2 ETS has achieved energy-saving and emission reduction effects in developing countries. Peter and Joseph [17] calculated the high carbon dioxide emissions from road transportation in India, and the results showed that from January to December 2016, about 960,830 tons of carbon dioxide were emitted into the atmosphere; Fuel consumption varies seasonally; Strict policies and technologies should be adopted to limit carbon dioxide emissions. Bottani et al. [18] assessed the economic and environmental sustainability of the fashion supply chain based on a model developed under Microsoft Excel, and calculated carbon dioxide emissions. The research results obtained most of the costs and sources of emissions, which can support the company's management's operational decisions.

The above content is the research on energy conservation and emission control by scholars in different fields, which can be seen to be able to measure the carbon emission of tourism and analyse the potential of emission reduction. In view of this, this study will measure the carbon emission of research area, and provide suggestions for the countermeasures of energy conservation and emission control in tourism.

3. Research on carbon emission measurement in the context of energy conservation and emission control

3.1. Model construction for measuring carbon emissions from tourism

Because of the aggravation of environmental problems, energy conservation and emission control have become the development trend of all industries. And energy conservation and emission control first need to measure carbon emissions, to facilitate the formulation of emission reduction policies, in view of the lack of mature theory and statistical data, tourism carbon emissions measurement currently has greater difficulties, the urgent need to build a suitable model for China's tourism carbon emitting measurement [19]. In the study, the model will be constructed using the equations. In this study, a model will be constructed using the formula "bottom-up" approach to estimate the carbon emitting generated from the main activities of tourists, which can be seen in Fig. 1.

In Fig. 1 the key activities for measuring carbon emitting from tourism include transportation, accommodation, tourism activities and food and beverage. Among these, the carbon emission measurement formula is shown in Eq. (1).

$$C = \sum_{i=1}^{n} C_a \tag{1}$$

where C is used to describe the total carbon emitting from tourism, C_a denotes the carbon emitting from the tourism sector of category a; n means the number of tourism sectors [20]. In this study, the carbon emitting from tourism transport, tourism lodging, tourism activities and tourism restaurants are measured, so $I = 4$.

In the measurement of carbon emissions from tourist traffic, given that tourist traffic is one of the components of passenger traffic and that the passenger mix of the two is very similar, the carbon emissions from passenger traffic are measured first, followed by the carbon emissions from tourist traffic.

In general, the amount of passengers and the distance travelled have a direct impact on the carbon footprint of passenger transport. The greater the amount of passengers transported and the greater the distance travelled, the greater the amount of energy consumed and therefore the greater the carbon emitting. The formula for measuring carbon emissions is shown in Eq. (2).

$$C_{ij} = F_i \cdot N_{ij} \cdot L_{ij} \tag{2}$$

where C_{ij} is used to describe the carbon emissions of transport trips, i, j, F_i indicates the carbon emission factor of i transport, N_{ij} means the number of passengers carried by transport $i{\cdot}j$ trips, L_{ij} indicates the distance carried by i transport j trips, and the units of the four parameters are $g{\cdot}CO_2$, $g{\cdot}CO_2/p{\cdot}km$, p and km, respectively. The formula for calculating the total carbon emitting from i is shown in Eq. (3).

$$C_{ij} = \sum_{j=1} C_{ij} = \sum_{j=1} \left(F_i \cdot N_{ij} \cdot L_i \right) = F_i \cdot \sum_{j=1} \left(N_{ij} \cdot L_{ij} \right) = F_i \cdot \bar{L} \cdot \sum_{ij=1} N_{ij} \tag{3}$$

where $\bar{L}$ is used to describe the average distance travelled. As an important indicator in tourism transport, passenger turnover reflects the total amount of tourism transport work carried out by the transport sector over a certain period and is also the main basis for transport planning [21]. Passenger turnover is the product of the amount of passengers and the distance travelled, and is expressed as in Eq. (4).

$$T = N \cdot \bar{L} \tag{4}$$

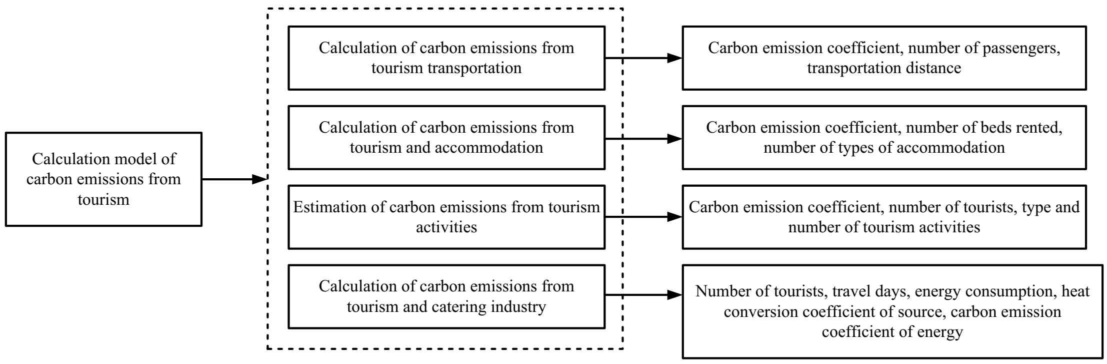

Fig. 1. Content of carbon emission calculation for tourism.

where T is used to describe the passenger turnover in p·km. From Eqs. (3) and (4) we can access the formula for calculating the total carbon emitting generated during the transportation of i means of transport, with the expression shown in Eq. (5).

$$C_i = F_i \cdot T_i \tag{5}$$

In other words, the carbon emitting of different categories of passenger traffic can be obtained by the product of the corresponding passenger turnover and carbon emission factors. Since part of the carbon emitting of passenger traffic consists of the carbon emissions of tourist traffic. Therefore, and thus the calculation for travel traffic carbon emissions is shown in Eq. (6).

$$C_T = \alpha \cdot C_{ij} \tag{6}$$

where C_T is used to describe the carbon emitting of tourism & transport and α represents the share of C_T in the carbon emitting of a type of passenger transport. Therefore, the measurement of carbon emitting from tourism transport can be obtained by Eq. (7).

$$C_T = F \cdot \alpha \cdot T \tag{7}$$

where F is used to describe the carbon emitting factors for different transport categories.

In the measurement of carbon emitting from tourist accommodation, as tourists mainly generate carbon emitting when using energy such as electricity, the carbon emitting from energy consumption by tourists in choosing various types of accommodation are summarised and calculated in the way shown in Eq. (8).

$$C_A = \sum_{k=1}^{m} \left(R_k \cdot N_k \right) \tag{8}$$

where C_A is used to describe the carbon emissions of tourist accommodation, R_k means the carbon emitting factor per bed per day for the accommodation type j, N_k is used to describe the actual amount of beds rented for the accommodation type and $j \cdot m$ indicates the amount of categories of accommodation type.

In the measurement of carbon emitting from tourism events, as the main energy consumption is electricity, the carbon emitting from this component are mainly measured. The expression of the measurement formula is shown in Eq. (9).

$$C_V = \sum_{h=1}^{l} \left(R_h \cdot N_h \right) \tag{9}$$

Eq. (9) is intended to be the product of the scale of visitor participation in all different types of tourism events and the carbon emissions of different types of tourism events. C_V it is used to describe the carbon emitting of tourism activities, R_h means the carbon emitting factor of tourism events h, N_h is used to describe the amount of visitors participating in tourism events h and n indicates the amount of types of tourism activities [22].

In the measurement of carbon emitting in the tourism catering industry, it mainly involves the carbon emitting generated from the consumption of electricity, gas and other energy in the production, storage and transportation processes, so some of the carbon emissions can be obtained by aggregating all the different types of energy consumption related to tourists and transforming them, with the expression shown in Eq. (10).

$$C_F = G \cdot D \cdot \sum_{y=1}^{g} \left(E_y \cdot \rho_y \cdot \alpha_y \right) \tag{10}$$

where C_F expresses the carbon emitting from tourism catering, G expresses the amount of visitors, D is used to describe the average amount of tourist days, E_y is used to describe the amount of the first y energy consumed by each tourist to provide daily catering, ρ_y expresses the heat conversion factor for the first y energy source, and α_y expresses the carbon emitting factor for the first y energy source (in terms of heat) [23].

3.2. Measurement of carbon emissions from tourism in research area

As the largest freshwater lake in China, Poyang Lake has superior natural conditions and a unique geographical location. Poyang Lake Eco-Economic Zone (E 114°41′-E 117°42′, N 27°42′-N 30°06′), as a special economic zone with both ecology and economy, takes Poyang Lake as its core area and Poyang Lake City Circle as its backing. The area, total year-end population and total economic volume are 30.67%, 50% and 60% of Jiangxi Province, respectively, and there are 38 counties as well as Poyang Lake in this special economic zone. The construction and development of research area has become a national strategy in 2009, and it has become a pioneer area for low-carbon economic development. Due to its superior historical and geographical conditions, it has rich natural, human and ecological tourism resources with a good combination situation and several world-class and national representative scenic spots. The process of measuring carbon emissions from tourism in research area can be seen in Fig. 2.

In the measurement of carbon emitting from tourism transport, it is essential to first determine the values of the parameters, which, as can be seen from Eq. (7), are the values of the mode of transport α, the carbon emission factor and the passenger turnover. Passenger turnover can be obtained from the Statistical Yearbook, while α and the carbon emission factor need to be further discussed at [24,25].

The modes of transport for the tourism are generally divided into civil aviation, rail, road and water transport, corresponding to aeroplanes, trains, automobiles and ships. Based on the relevant circumstances, it is possible to determine the values of α for the four types of transport for the tourism. As the carbon emission intensity of railways and the energy consumption level of civil aviation in China are lower than those of developed countries, the carbon emission factors of civil aviation and railways are the lowest values of carbon emission factors of domestic and foreign transport modes. At the same time, the energy consumption quality of similar small cars in China is higher than that of developed

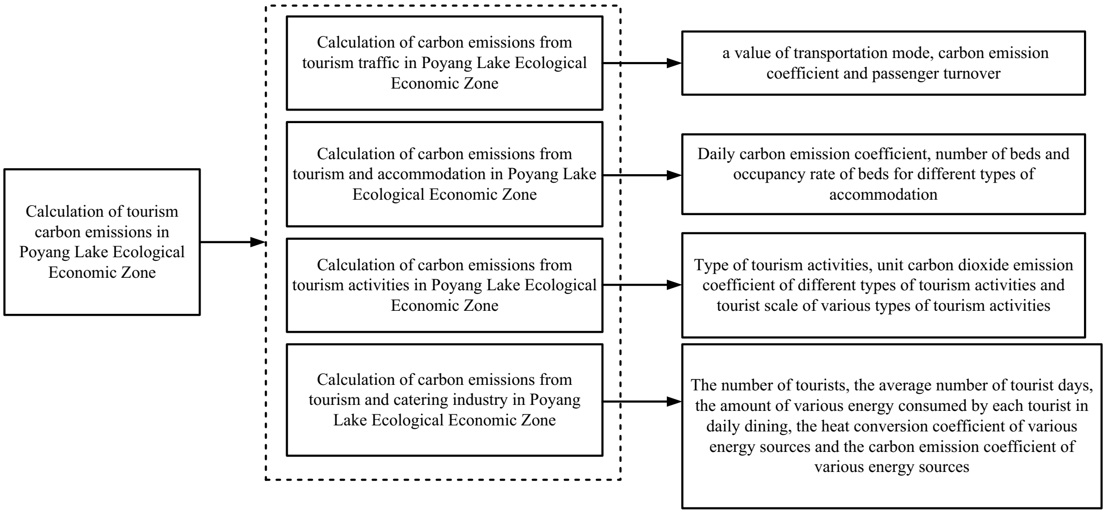

Fig. 2. Calculation process of tourism carbon emitting in research area.

countries, while the level of business cars is not much different, so the carbon emitting coefficient of roads is the highest value of carbon emitting coefficient of domestic and foreign transportation modes; similarly, the carbon emitting coefficient of water transportation can also be determined. From this, we can get α value, carbon emitting coefficient and passenger turnover of transportation modes, and we can calculate the carbon emission of tourism and transport in research area.

In the process of measuring carbon emitting from tourism lodging, the relevant parameters also need to be determined, as can be seen through Eq. (8), the type of accommodation sector, the carbon emission factor per bed per day for different types of accommodation, the amount of beds and the bed occupancy rate need to be clarified. Based on the actual situation of the tourism accommodation sector in Jiangxi Province and the relatively detailed statistics of star hotels, the star hotels in the study area were used as the object of study for the tourism accommodation sector in this study, and the accommodation forms were divided according to star hotels [26,27]. Based on the specific situation of the tourism accommodation sector in the study area, it was possible to determine the carbon emitting factor per bed per night; and to estimate the amount of hotel beds and bed occupancy rate of star-rated hotels in Jiangxi based on their actual situation. From this, the carbon emitting of star-rated hotels in each region of the study area can be obtained by substituting the relevant data into the formula. However, measuring the carbon emissions of star-rated hotels alone makes the results much smaller and does not correspond to the actual situation. To be closer to the real situation and to simplify the study process, the carbon emissions of star-rated hotels are expanded by a factor of 10 to represent the carbon emitting of the entire tourism lodging industry.

Similarly, the measurement of carbon emitting from tourism events still requires the determination of relevant parameters, which, according to Eq. (9), include the type of tourism activity, the coefficient of carbon dioxide emissions per unit for various types of tourism activities and the size of visitors to each type of tourism activity [28,29]. Based on the actual situation, the tourism activities in the research area are divided into six categories, namely tourism, leisure and holiday, business trip, visiting friends and relatives, health and recreation and others, and the energy consumption and CO_2 emission factors for these tourism activities can be obtained through relevant information [30,31]. The proportion of various types of tourism events can be obtained by combining the composition of tourism numbers and the number of tourists in each region of Jiangxi Province, and the scale of tourists for the six types of tourism activities in the study area can be calculated. The carbon emissions of tourism events in the research area can then be obtained by bringing the parameters into the equation.

Finally, the carbon emitting of the tourism catering industry are measured. Eq. (10) shows that it is necessary to first determine five parameters: the amount of tourists, the average amount of tourist days, the amount of various energy consumed by each tourist per day, the heat conversion factor of various energy sources and the carbon emission factor of different energy sources [31–33]. These five parameters can be obtained from relevant statistics or calculations, which in turn can be used to find the carbon emitting of the tourism catering industry in each region of the study area.

After measuring the carbon emitting from tourism & transport, tourism lodging, tourism events and tourism catering in the study area, they are brought into Eq. (1) to be able to find the total carbon emissions of each sector of tourism in the research area.

4. Analysis of the results of measuring carbon emissions from tourism in research area

4.1. Analysis of carbon emission measurement results of various sectors of tourism in research area

After determining the parameters related to carbon emissions from tourism traffic as described in the study methodology, the results of carbon emitting from tourism traffic in Poyang Lake Eco-Economic Zone in 2012 were calculated, which is can be seen in in Table 1.

Table 1 shows that of the four different modes of transport, the carbon emissions are, in descending order, from road, rail, air and water transport, accounting for 49.1%, 35.84%, 15.03% and 0.03%, respectively. The reason for this is that in 2012, the overall economy of Jiangxi Province had not yet been fully developed and the three-dimensional transport network had not yet been fully built, so carbon emissions from navigation were lower than those from roads and railways. The 2012 carbon emitting from tourism in each region of the research area can be seen in Table 2.

From Table 2 that the carbon emissions from tourism & transport, tourism lodging, tourism events and tourism catering are 1,146,000; 626,800; 133,700 and 95,100 tons, respectively, accounting for 57.25%, 31.31%, 6.68% and 4.75% of the carbon emissions from tourism in research area in 2012. After determining the parameters related to carbon emissions from tourism accommodation as described in the research methodology, the carbon emitting of different star-rated hotels in the study area in 2012 were calculated and the results can be seen in Table 3.

Table 3 shows that among the different star-rated hotels, the carbon emissions of three- and four-star hotels are relatively high, accounting for 86.01% of the star-rated hotels, which is related to the supporting facilities and the price of accommodation. Among them, five-star hotels have better supporting facilities, but because of their expensive price, fewer tourists choose hotels of this level, so they consume less energy, making carbon emissions lower. Similarly, the

Table 3
Carbon emissions of different star hotels in the study area in 2012 (unit: 10,000 tons)

Project	Five-star	Three-star and four-star	One-star and two-star	Total
Nanchang	0.0524	0.9343	0.0996	1.0863
Jiujiang	0.0573	1.0227	0.1090	1.1890
Jingdezhen	0.0340	0.6013	0.0639	0.6992
Shangrao	0.0442	0.7816	0.0833	0.9091
Fuzhou	0.0179	0.3240	0.0343	0.3762
Xinyu	0.0126	0.2210	0.0236	0.2572
Ji'an	0.0439	0.7859	0.0834	0.9132
Yichun	0.0203	0.3660	0.0389	0.4252
Yingtan	0.0200	0.3541	0.0380	0.4121
Total	0.3026	5.3909	0.5740	6.2675

Table 1
Results of carbon emitting from tourism and transportation in the study area in 2012 (unit: 10,000 tons)

Project	Railway	Highway	Water transport	Aviation	Total
Nanchang	7.119	9.753	0.004	2.990	19.866
Jiujiang	7.789	10.669	0.007	3.270	21.735
Jingdezhen	4.579	6.276	0.002	1.919	12.776
Shangrao	5.960	8.160	0.005	2.500	16.625
Fuzhou	2.470	3.381	0.003	1.029	6.883
Xinyu	1.684	2.305	0.002	0.707	4.698
Ji'an	5.989	8.204	0.002	2.512	16.707
Yichun	2.786	3.816	0.001	1.170	7.773
Yingtan	2.700	3.700	0.003	1.133	7.536
Total	41.076	56.264	0.029	17.230	114.599

Table 2
Carbon emitting of tourism in each region of the study area in 2012 (unit: 10,000 tons)

Project	Tourism transportation	Tourism and accommodation industry	Tourism activities	Tourism catering industry	Total
Nanchang	19.86	10.88	2.10	1.51	34.35
Jiujiang	21.73	11.90	2.37	1.69	37.69
Jingdezhen	12.80	7.00	1.60	1.16	22.56
Shangrao	16.60	9.10	2.00	1.39	29.09
Fuzhou	6.90	3.76	0.78	0.56	12.00
Xinyu	4.70	2.56	0.52	0.41	8.19
Ji'an	16.69	9.13	2.00	1.39	29.21
Yichun	7.80	4.24	1.10	0.81	13.95
Yingtan	7.52	4.11	0.90	0.59	13.12
Total	114.60	62.68	13.37	9.51	200.16

price of one- and two-star hotels is lower due to the smaller scale of their amenities, so their carbon emissions are lower due to less energy consumption. Three- and four-star hotels, on the other hand, because of their moderate prices and medium-sized amenities, have a higher number of visitors choosing this level of accommodation, which ends up generating a higher energy consumption and a higher carbon footprint. Where Table 3 is only the carbon emitting of the different star hotels in the study area, due to the variety of accommodation options in the area, it is possible to expand this value by a factor of ten to represent the carbon emitting of the entire tourism accommodation sector in the research area, meaning that the carbon emitting of tourism accommodation in the research area were approximately 626,800 tons in 2012. After determining the parameters related to carbon emitting from tourism activities, as described in the research methodology, it was possible to calculate the carbon emitting from tourism activities in the research area in 2012, and the results can be seen in Table 4.

In Table 4, the carbon emitting from the different types of tourism activities in the study area are, in descending order, leisure and holiday, visiting friends and relatives, business trips, sightseeing trips, health care and others. In the case of leisure and holiday activities, more energy is consumed and therefore the highest carbon emissions are generated. Similarly, after determining the parameters related to carbon emissions from the tourism and catering sector as described in the research methodology, it was possible to calculate the carbon emissions from the catering sector in the study area in 2012, which was 95,100 tonnes. For reasons of space and the relatively small amount of carbon emissions from the tourism and catering sector, the carbon emissions from each energy source are not presented in a table.

By measuring the carbon emitting of the various components of tourism in the study area, it can be seen that the four sectors, in descending order, are tourism & transport, tourism accommodation, tourism activities and tourism catering, with carbon emissions of 1,146,000; 626,800; 133,700 and 95,100 tonnes, respectively. They accounted for 57.25%, 31.31%, 6.68% and 4.75% of all carbon emissions, respectively, meaning that tourism transportation has a greater potential to reduce emissions.

4.2. Analysis of carbon emission measurement results of tourism in each region of Poyang Lake ecological and economic zone

Using Tables 1–4, the share of carbon emitting in the different tourism sectors can be calculated for each region of the study area and the results are shown in Fig. 3.

Fig. 3a–d show the share of carbon emissions from different tourism sectors in tourism and transport, tourism lodging, tourism events and tourism catering in each region of the study area, respectively. The share of carbon emissions from tourism and transport, tourism lodging, tourism events and tourism catering sectors in Jiujiang City are 18.97%, 18.97%, 18.03% and 18.07%, respectively; followed by Nanchang City, Ji'an City and Shangrao City, which have a higher share of carbon emissions. Among them, the total carbon emitting share of each region is shown in Fig. 4.

From Fig. 4, the nine cities in the research area had the highest to lowest carbon emissions from tourism in 2012, namely Jiujiang, Nanchang, Ji'an, Shangrao, Jingdezhen, Yichun, Yingtan, Fuzhou and Xinyu, of which Jiujiang and Nanchang are rich in tourism resources, have many world-class and national tourist attractions and are important economic development areas in the study area. Therefore, they have more travellers, that is, higher carbon emitting from tourism traffic, compared to other cities. The carbon emissions of Jiujiang, Nanchang, Ji'an and Shangrao are larger, accounting for 65.11% of the carbon emitting from tourism in the whole Poyang Lake Ecological and Economic Zone. Therefore, these four cities have great potential for emission reduction and are the key areas for emission reduction in the region. The carbon emission of each tourism sector in each region of the study area is shown in Fig. 5.

As can be seen from Fig. 5, among the nine municipalities located in the study area, the total carbon emissions are, in descending order, Jiujiang, Nanchang, Ji'an, Shangrao, Jingdezhen, Yichun, Yingtan, Fuzhou and Xinyu. In the four sectors of tourism catering, tourism events, tourism lodging and tourism & transport, the carbon emissions are, in descending order, transportation, accommodation, activities and catering.

Table 4
Carbon emitting from tourism activities in the study area in 2012 (unit: 10,000 tons)

Project	Tourism	Leisure vacation	Business travel	Visit relatives and friends	Health care	Other	Total
Nanchang	0.260	0.996	0.318	0.480	0.021	0.009	2.084
Jiujiang	0.300	1.154	0.369	0.554	0.024	0.010	2.411
Jingdezhen	0.200	0.760	0.239	0.367	0.019	0.007	1.592
Shangrao	0.243	0.945	0.303	0.455	0.020	0.008	1.974
Fuzhou	0.099	0.387	0.121	0.188	0.010	0.003	0.808
Xinyu	0.068	0.255	0.083	0.126	0.005	0.004	0.541
Ji'an	0.245	0.949	0.305	0.460	0.020	0.008	1.987
Yichun	0.135	0.524	0.166	0.249	0.011	0.006	1.091
Yingtan	0.110	0.420	0.136	0.201	0.010	0.005	0.882
Total	1.66	6.39	2.04	3.08	0.14	0.06	13.37

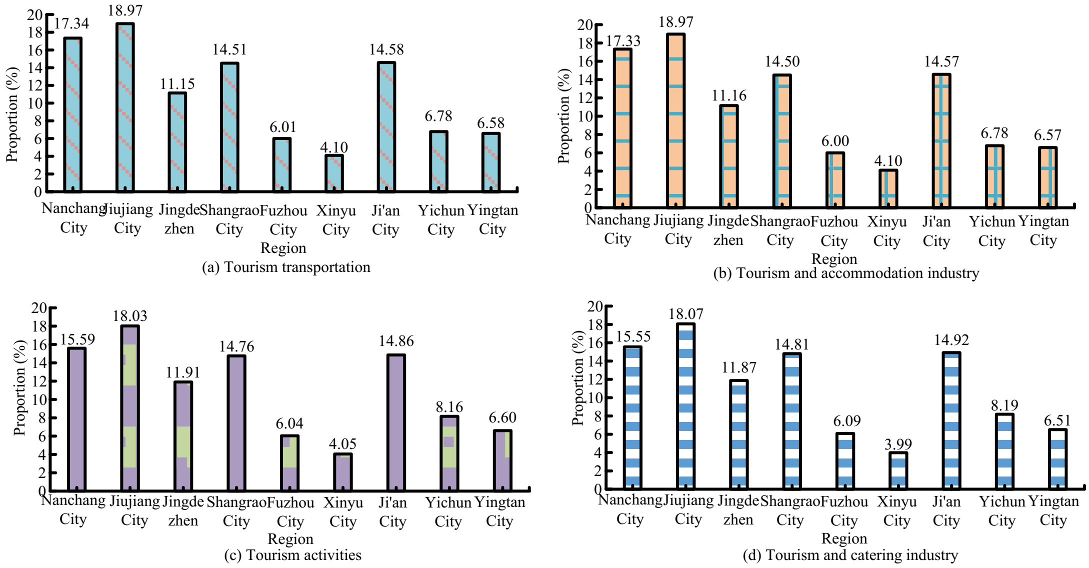

Fig. 3. Proportion of carbon emitting in various tourism sectors in the study area.

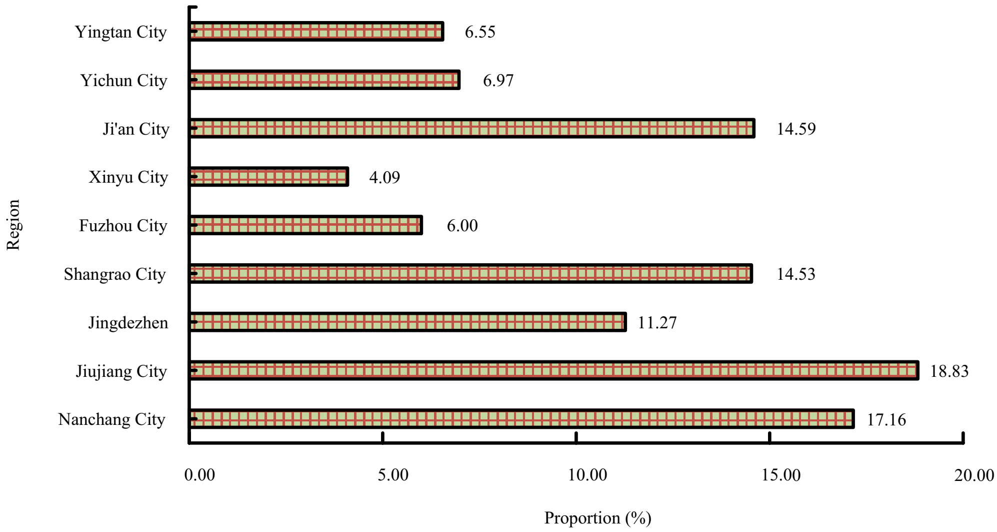

Fig. 4. Proportion of total carbon emissions by region.

5. Conclusion

As the environmental problems become more and more serious, energy conservation and emission control become the important development trend of various industries, and tourism is no exception, it needs to achieve energy conservation and emission control, and develop low carbon economy. Tourism is a highly dependent industry on the environment and climate, and it is also a very complex system. Therefore, when there are contradictions between climate, environment, and tourism, we must pay more attention to them in order to achieve coordinated social development. In order to achieve the sustainable development of the tourism industry, we need to find a way under the current climate conditions. Therefore, energy conservation and emission reduction have become the voice of the development of the tourism industry. One of the important elements of energy conservation and emission control is the measurement of carbon emission, the study uses the formula to construct the carbon emission measurement model of tourism, and measures the carbon emission of various sectors and regions of tourism in study area. The measurement results show that among the nine cities located in Poyang Lake Ecological Economic Zone, the total carbon emission is Jiujiang, Nanchang, Ji'an, Shangrao, Jingdezhen, Yichun, Yingtan, Fuzhou and Xinyu in the order of highest to lowest; the carbon emission of Jiujiang, Nanchang, Ji'an and Shangrao reaches 65.15% of the total carbon emission of tourism in Poyang Lake Ecological Economic Zone, which has great potential of energy conservation and emission control. Among the four sectors of tourism catering, tourism events, tourism

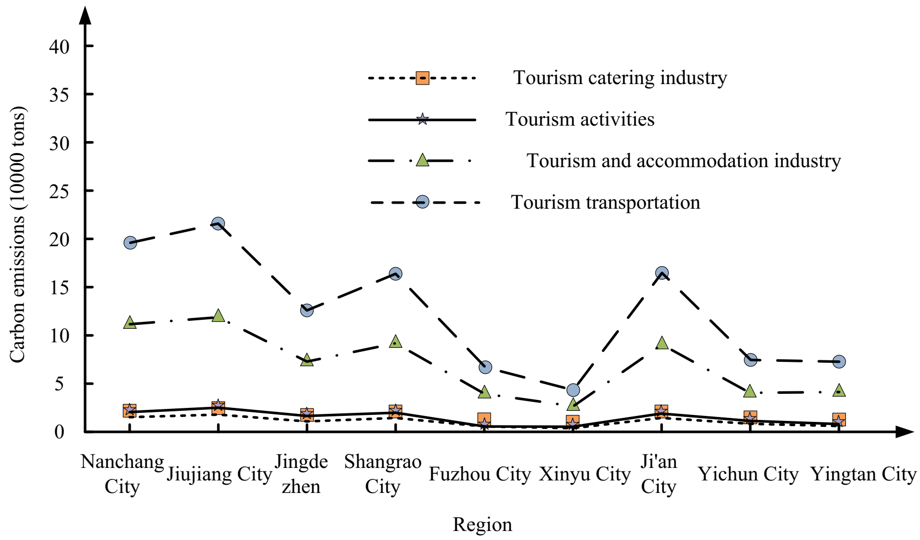

Fig. 5. Carbon emissions of tourism departments in various regions of study area.

lodging and tourism & transport, the carbon emissions are transportation, accommodation, activities and catering in descending order, and tourism transportation accounts for 57.25% of all carbon emissions, which the potential for energy conservation and emission control is significant. Due to the differences between existing measurement methods, the calculated carbon emissions from tourism in different countries and regions cannot be compared with each other. Therefore, in order to facilitate comparison and reduce the difficulty of research, further research will be conducted on the unified measurement model standards in the future.

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