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# Temporal and Spatial Evolution of Carbon Emissions and Their Influencing Factors for Tourist Attractions at Heritage Tourist Destinations

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**Abstract:** Carbon emissions play an important role in sustainable tourism development at heritage sites. The study takes the Wulingyuan Scenic and Historic Interest Area (WSHIA) as an example, and primary and secondary data sources are used to measure and estimate the carbon emissions of tourist attractions from 1979 to 2014. The temporal and spatial evolution of carbon emissions and their influencing factors for tourist attractions at heritage tourist destinations are analyzed. The results show that there are great differences in carbon emissions per visitor across the different types of tourism attractions at the heritage tourist destination, and there are significant monthly and interannual differences in the carbon emissions of the tourism attractions in the WSHIA. The main influencing factors include tourism seasonality, the rapid growth of China's tourism market, and the rising popularity of heritage tourism. The spatial evolution of carbon emissions of the tourist attractions can be divided into three stages, and its main influencing factors include functional zoning and environmental regulation at the heritage sites and diversified evolution of the heritage tourist attractions. The findings of this study could enrich theories of low-carbon tourism and provide the low-carbon development measures of sustainable tourism in heritage tourist destinations for policymakers.

**Keywords:** carbon emissions; tourist attractions; heritage tourist destination; temporal and spatial evolution; influencing factors; sustainable tourism

## 1. Introduction

Tourism has been recognized as a significant greenhouse gas (GHG) emissions source on a global scale by UNWTO-UNEP-WMO [1] and Gössling [2]. For many years, research on energy consumption and carbon emissions of the tourism industry has been widely carried out and discussed in the hope of promoting energy conservation and emission reductions [3]. Previous studies have focused on the estimation of tourism-related carbon emissions under different spatial scales; for example, at the political and economic entity scale like the European Union [4,5], at the country scale [6–9], at the regional scale [10,11], at the city scale [12,13], and at the tourist destination scale [14–16]. Moreover, a lot of studies have focused on accounting for the carbon emissions of different tourism sectors, such as tourism transportation [3,17–20], tourism accommodation [21–25], tourist attractions and

activities [25–28] and others. Previous findings on energy and CO<sub>2</sub> emissions in the tourism industry mainly focus on three sectors: transportation, accommodation, and activities [17,18]. Many studies have indicated that transportation and accommodation account for a large portion of the energy consumption and CO<sub>2</sub> emissions in the tourism industry [1,9]. There are few studies on energy consumption and carbon emissions of tourist attractions and activities when compared to tourism transportation and accommodation. Tourist attractions and activities, considered as a sub-sector in the conceptual framework for tourism satellite accounts (TSA) of the WTO (1999), constitute the core of the tourism product [17]. A study shows that the proportion of carbon emissions of tourist attractions and activities from the whole tourism industry is 22.46% at the destination in 2015 [15]. It can be concluded that carbon emissions from tourist attractions and activities are very important and the corresponding data is lacking in the study of sustainable tourism, so this paper tries to fill this gap through calculating and analyzing carbon emissions of tourist attractions and activities.

World Heritage Sites are the most important tourist attractions in the world. According to the statistics of the United Nations Educational Science and Cultural Organization (UNESCO), the World Heritage List consists of 1121 World Heritage Sites, including 869 cultural sites, 213 natural sites, and 39 mixed sites as of July 2019. While the basic objective of UNESCO in the designation of the World Heritage Sites is to promote their protection and preservation, some destinations are prioritizing their tourist development [29]. Many studies show that the development of tourism could promote the rapid socio-economic development of natural heritage sites and the effective protection of heritage resources [30,31]. However, many heritage tourism sites are facing natural threats such as climate change, fragile ecosystems, and the pressure of resources and environment brought by the rapid development of the tourism industry [15,32–34], the reduction of biodiversity and ecological safety index [35,36], prominent impaired universal values [37,38], over-commercialization [39], serious waste [40], impaired quality of heritage landscape resources [41,42] and a slew of other issues. Some of the World Heritage Sites have been given a yellow card warning by the UNESCO World Heritage Committee because of some of the issues mentioned above [43].

How to correctly understand and reasonably cope with the various ecological threats and environmental pollution in the development of heritage tourism has become an important research topic for the sustainable development of World Heritage Sites [42,44–46]. Many scholars have performed quantitative research on the sustainable development of heritage tourism sites from the aspects of resources [33], energy [16,47], environment [48,49], and ecology [50]. However, to our knowledge, only a few scholars have paid attention to the energy consumption and carbon emissions of tourism at heritage tourism sites [3,16,20,50]. As for the research method, the main measurement and analysis methods of carbon emissions commonly used by scholars are "bottom-up" analysis methods [18], "top-down" analysis methods [26], ecological footprint analysis [51], life cycle analysis [52], expenditure approaches [53], input-output analysis [54], Tourism Satellite Account [55]. Among them, the "bottom-up" method, which analyzes the data of tourists arriving at the destination from the perspective of tourists, and calculates the carbon emissions of each link of tourism step by step, when the data is more continuous and available, is mostly used. Therefore, this paper attempts to fill this gap by calculating carbon emissions from different types of tourist attractions and tourist activities at heritage tourist sites using the "bottom-up" method.

Functional zoning is an important way for the scientific protection of resources and the environment and the rational development of the social economy at the World Heritage Sites. Many scholars have studied the spatial division of heritage sites [33,56,57]. There may be an interactive relationship between the functional zoning of heritage sites and tourist activities. Functional zoning may inhibit the planning and organization of tourism activities in the space of heritage sites, and tourist activities may also affect the effective protection of heritage sites. At present, there are few findings related to the protection of heritage sites and their sustainable development of tourism. Some scholars have performed research on the spatial-temporal evolution pattern of tourism lands at the Natural World Heritage Site [33], the relationship between heritage, recreational quality and geomorphological vulnerability in the coastal

zone [58], and assessment of urban cultural-heritage protection zones [56]. Based on the different tourist attractions and activities in each functional zoning of heritage sites, this paper attempts to analyze the temporal and spatial evolution of carbon emissions and its influencing factors for tourist attractions at a heritage tourist destination.

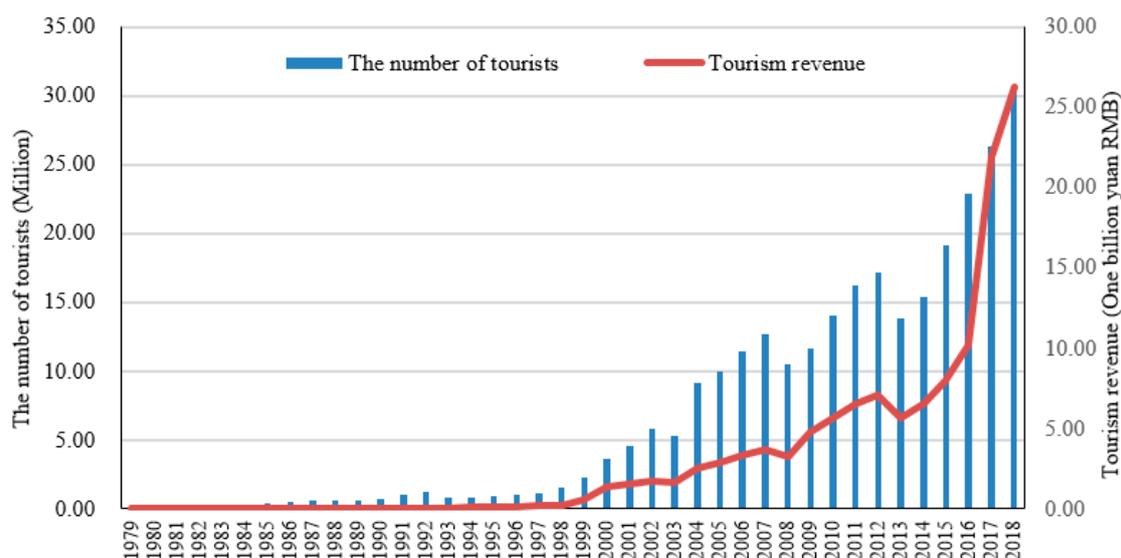
As of July 2019, China has fifty-five world cultural, landscape, and natural heritage sites listed in the World Heritage List, ranking first in the world. Many World Heritage Sites in China have become among the most popular tourist destinations for domestic and foreign tourism. Taking the Wulingyuan Scenic and Historic Interest Area (WSHIA) as the study site, this paper attempts to measure and estimate the carbon emissions of tourist attractions from 1979 to 2014 at the heritage tourist destination using a bottom-up approach that utilizes primary and secondary data sources, and analyzes the characteristics of its temporal and spatial evolution.

On one hand, through analyzing carbon emissions from tourist attractions and activities, this study fills the research gap on carbon emissions from tourist attractions at heritage sites. Moreover, this research will enrich the theory of low-carbon tourism and tourism geography and heritage protection and utilization, construct the theory of temporal and spatial evolution of carbon emissions and its influencing factors for tourist attractions at heritage tourist sites, and promote the sustainable tourism development of heritage site from the perspective of low carbon. On the other hand, studying the temporal and spatial evolution of carbon emissions and their influencing factors for tourist attractions at heritage tourist sites will help local government agencies and institutions at heritage sites better evaluate the level of sustainable development of tourist attractions from the perspective of the carbon emissions and examine the factors affecting the temporal and spatial evolution of carbon emissions. It provides policymakers with ideas to formulate more effective policies to scientifically protect heritage sites and at the same time enhance energy conservation and emission reduction in the tourism industry at the heritage tourist site.

The paper is structured as follows: the next section provides a brief overview of the study area. The third section describes the methodology used in classifying the tourist attractions, calculating and estimating CO<sub>2</sub> emissions, analyzing the temporal and spatial evolution of carbon emissions and data acquisition and explains the source of data of the average energy per unit heat and CO<sub>2</sub> emission coefficients. Section four shows the carbon emission per tourist of different tourist attractions, analyses the evolution of time pattern of carbon emissions of tourist attractions and uses ArcGIS to analyze its spatial pattern, and identifies the factors affecting the evolution of the spatial-temporal pattern of carbon emissions. Finally, we discuss some related problems, conclusions and policy recommendations, and the limitations of this paper and future research directions.

## 2. Study Area

The WSHIA (29°16' N–29°24' N and 110°22'–100°41' E) is located in Hunan Province, China, and covers an area of approximately 397.6 km<sup>2</sup>. The WSHIA has interesting geomorphology characterized by a peculiar and attractive landform, ecosystem integrity, rare geological landscape, and variable microclimate [15]. It has been offering forest sightseeing activities in Zhangjiajie Forest Farm since 1979. With the approval of the State Council of the People's Republic of China in September of 1982, the original Zhangjiajie Forest Farm was officially named "Zhangjiajie National Forest Park" and became the first national forest park in China. In December 1992, the area was listed as a natural heritage site by UNESCO and registered on the organization's World Heritage List (Advisory Body Evaluation). In the past 40 years, the tourism industry in WSHIA had experienced rapid development. By 2014, sixteen tourist attractions had been completed. According to the Wulingyuan Bureau of Statistics, tourist arrivals increased from 10,000 in 1979 to 30.29 million in 2018 and tourism revenue increased from dozens of thousands to 26.25 billion RMB (WBS, 2005, and Annual Statistic Bulletin) (Figure 1). The tourism industry has become the most important industry for the local economy in the WSHIA [16].



**Figure 1.** The number of tourists and tourism revenue in the WSHIA during 1979–2018. Data sources: Author’s calculation from Wulingyuan Bureau of Statistics (2005, 2011) and Annual statistic bulletin.

### 3. Method and Data Source

#### 3.1. Classification of the Tourist Attractions

Swarbrooke defines four categories of attractions: natural attractions, man-made attractions built for other purposes than attracting tourists, man-made attractions built to attract tourists, and man-made attractions built for special events [59]. Using the above classification method, tourist attractions in the WSHIA are divided into three categories: natural attractions, man-made attractions built for other purposes than attracting tourists, and man-made attractions built to attract tourists. The three categories are composed of eleven specific types, such as natural sightseeing, natural sightseeing via low-emission buses, natural sightseeing via cableways, and so on, as shown under the column named “Basic Types” in Table 1.

**Table 1.** Types of various tourist attractions in the WSHIA and their carbon emissions per visitor.

Main Categories	Basic Types	Tourist Attractions	Carbon Emissions Per Visitor (kg/p)	Sources
Natural attractions	Natural sightseeing	Zhangjiajie National Forest Park, Helong Park	0.42	Becken et al. [26] and Kuo and Chen [28]
	Natural sightseeing via low-emission buses	Wujiayu Sightseeing Spot, Tianzi Mountain, Yangjiajie Sightseeing Spot, and Stream-circling Valley Sightseeing Spot	1.24	Becken et al. [26] and Kuo and Chen [28] in combination with our investigation and calculations
	Natural sightseeing via cableways	Tianzi Mountain Sightseeing Cableway	0.50	Our investigation and calculations
		Huangshizhai Sightseeing Cableway	0.64	Our investigation and calculations
	Natural sightseeing via electric trains	Ten-li Gallery Boutique Route	1.25	Our investigation and calculations
	Natural sightseeing via elevators	Bailong Sightseeing Elevators	0.23	Our investigation and calculations
	Cave sightseeing with light show	Huanglong Cave	1.35	Our investigation and calculations
Lake sightseeing via electric boats	Baofeng Lake	0.50	Our investigation and calculations	

Table 1. Cont.

Main Categories	Basic Types	Tourist Attractions	Carbon Emissions Per Visitor (kg/p)	Sources
Man-made attractions built to attract tourists	Tourism performance	Charming Xiangxi Performance	1.54	Our investigation and calculations
	Unpowered tourist aquatics	Whitewater Slalom	0.42	Becken et al. [26] and Kuo and Chen [28]
Man-made attractions built for other purposes than attracting tourists	Religious and cultural attractions	Zixia Taoist Temple	0.17	Becken et al. [26] and Kuo and Chen [28]
	Museum	China Giant Salamander Biotechnology Museum	5.14	Our investigation and calculations

### 3.2. Calculation of Carbon Emission at the Tourist Attractions

For the calculation below, we use  $j$  to index the different types of tourist attractions (e.g., natural sightseeing, natural sightseeing via low-emission buses, natural sightseeing via cableways, and others) and  $k$  to index the different tourist attractions (e.g., Zhangjiajie National Forest Park, Helong Park, and others). The CO<sub>2</sub> emission coefficient per unit quantity consumption of the different fuel types is available for a certain tourist attractions listed in Section 3.4.

According to the energy consumption data of tourist attractions at the WSHIA in 2010 and 2014, the quantitative methods of carbon emission of various kinds of tourist attraction in heritage sites are divided into two types: measurement and estimation, the specific calculation formula is shown in Sections 3.2.1 and 3.2.2, respectively. Given the unavailability of energy consumption data before 2005, we have to estimate the carbon emissions of tourism attractions at the WSHIA during this period, as detailed in Section 3.2.3.

#### 3.2.1. The Calculation of Carbon Emission at the Different Types of Tourist Attractions in 2010 and 2014

When the quantity consumption of the different fuel types are available for a type of tourist attraction at the WSHIA, the amount of CO<sub>2</sub> emission of the  $j$ -th type of tourist attraction in the WSHIA is computed by:

$$C_j = \sum_{i=1}^{n_i} (f_i \times CEC_i) \quad (1)$$

where  $n_i$  represents the number of different fuel types,  $f_i$  represents the quantity of the  $i$ -th fuel type, and  $CEC_i$  represents the CO<sub>2</sub> emission coefficient per unit quantity of the  $i$ -th fuel type. These tourist attractions are identified by “our investigation and calculations” under the “Sources” column in Table 1, which include Wujiayu Sightseeing Spot, Tianzi Mountain, Yangjiajie Sightseeing Spot, Stream-circling Valley Sightseeing Spot, Tianzi Mountain Sightseeing Cableway, Huangshizhai Sightseeing Cableway, Ten-li Gallery Boutique Route, Bailong Sightseeing Elevators, Huanglong Cave, Baofeng Lake, Charming Xiangxi Performance, and China Giant Salamander Biotechnology Museum.

#### 3.2.2. The Estimation of Carbon Emission of the Seven Types of Tourist Attractions in 2010 and 2014

When the quantity consumption of the different fuel types are not available for a type of tourist attraction at the WSHIA, we utilize the values of carbon emissions per visitor in Becken et al. [26] and Kuo & Chen [28] by matching the characteristics of our tourist attractions to those in Becken et al. [26] and Kuo & Chen [28]. These are denoted by “Becken et al. [26] and Kuo and Chen [28]” under the “Sources” column in Table 1.

The CO<sub>2</sub> emission of the  $j$ -th type of tourist attraction in the WSHIA is then estimated by:

$$C_j = \sum_{k=1}^{n_k} (C_k \times A_k) \quad (2)$$

where  $n_k$  represents the number of different tourist attractions that fall into the  $j$ -th type of tourist attraction,  $C_k$  represents CO<sub>2</sub> emission per visitor from the  $k$ -th tourist attraction that belongs to the

$j$ -th type of tourist attraction, and  $A_k$  represents the number of visitors at the  $k$ -th tourist attraction that belongs to the  $j$ -th type of tourist attraction.

These tourist attractions are identified by “Becken et al. [26] and Kuo and Chen [28]” in combination with our investigation. They are listed under the “Sources” column in Table 1, which includes Zhangjiajie National Forest Park, Helong Park, Wujiayu Sightseeing Spot, Tianzi Mountain, Yangjiajie Sightseeing Spot, Stream-circling Valley Sightseeing Spot, Whitewater Slalom, and Zixia Taoist Temple.

### 3.2.3. The Estimation of Carbon Emission of Tourist Attractions in 1979–2005

Because the energy consumption data before 2005 are not available, we cannot directly measure the carbon emissions of tourism attractions at the WSHIA; we can only estimate the carbon emissions of tourist attractions in heritage sites during this period. Data on carbon emission per visitor of each tourist attraction for 2010 and 2014 are used to extrapolate the relevant data for carbon emissions of each tourist attraction for 1979, 1989, 1995, 2000, and 2005 respectively. Hence, the CO<sub>2</sub> emission per visitor at a certain type of tourist attraction in the WSHIA is computed by:

$$CP_j = C_j / VN_j \quad (3)$$

where  $CP_j$  represents CO<sub>2</sub> emission per visitor at the  $j$ -th type of tourist attraction,  $C_j$  represents CO<sub>2</sub> emission at the  $j$ -th type of tourist attraction,  $VN_j$  represents the number of visitors at the  $j$ -th type of tourist attraction. Hence, the CO<sub>2</sub> emission of a certain type of tourist attraction at the WSHIA for 1979, 1989, 1995, 2000, and 2005 is computed by:

$$C_j = CP_j \times VN_j \quad (4)$$

### 3.2.4. The Total Carbon Emission from All Types of Tourist Attractions from 1979 to 2014

The total CO<sub>2</sub> emission from all types of tourist attractions in the WSHIA for a particular year is computed by:

$$C = \sum_{j=1}^{n_j} C_j \quad (5)$$

where  $C$  represents total CO<sub>2</sub> emission of the  $j$ -th type of tourist attraction for a particular year and  $n_j = 11$  represents the number of different types of tourist attractions.

### 3.3. The Analysis Method of the Temporal and Spatial Evolution of Carbon Emissions

By using the method of mathematical statistics analysis, the monthly and interannual characteristics of the evolution of the carbon emission of tourist attractions of the heritage sites are analyzed. We use ArcGIS to analyze its spatial evolution characteristics.

### 3.4. Data Acquisition

The data are obtained mainly through the following two sources: on the one hand, the data on energy consumption of the nine types of tourist attractions identified by “our investigation and calculations” under the Sources column in Table 1 were collected through questionnaire survey, in-depth interviews, and field investigations from various tourism enterprises and government tourism management departments. We have conducted questionnaire survey among the management department of tourist attractions and carried out depth interviews with Wulingyuan District Tourism Bureau and tourism attraction management enterprises. And field investigations of the tourist attractions’ energy consumption were conducted in the WSHIA over 30-day periods in January and July of 2011, January of 2012, July of 2015, and February of 2016.

The energy data of low-emission buses came from Zhangjiajie YiCheng International Environmental Protection Passenger Transport Co., Ltd. Energy data for Huangshizhai Sightseeing

Cableway, Tianzi Mountain Sightseeing Cableway and Yangjiajie Sightseeing Spot came from their management companies. The energy data of Bailong Sightseeing Elevators came from Zhangjiajie Bailong Sightseeing Elevators Tourism Development Co., Ltd. Ten-li Gallery Boutique Route, Huanglong Cave, Baofeng Lake's energy data came from its management office. Charming Xiangxi Performance's energy data came from Zhangjiajie charming Xiangxi Tourism Development Co., Ltd. China Giant Salamander Biotechnology Museum's energy data came from Zhangjiajie (China) Giant Salamander Biotechnology Co., Ltd.

On the other hand, tourist arrivals of each tourist attraction in 1979, 1989, 2000, 2005, 2010, and 2014, were obtained from the statistical yearbooks, local chronicles, etc., such as the Statistical Yearbook of the Wulinyuan Region (2005–2010 & 1989–2004), the local annual statistic bulletin, the Statistical Yearbook of Zhangjiajie City, and local chronicles of the Wulinyuan region.

### 3.5. The Average Energy Per Unit Heat and CO<sub>2</sub> Emission Coefficient

The CO<sub>2</sub> emission coefficients for each type of fuel are obtained from Schedule 1 of the China Energy Statistical Yearbook 2010, and they are as follows: 3.1605 kgCO<sub>2</sub>/kg for diesel, 2.9848 kgCO<sub>2</sub>/kg for gasoline, and 2.4994 kgCO<sub>2</sub>/m<sup>3</sup> for liquid natural gas [60]. You et al. [61] provides results on the CO<sub>2</sub> emission coefficient of electric power (0.798 kg/kWh) cited and used in this paper. Due to their small fluctuation over the period of 1979–2014, this paper assumes that the CO<sub>2</sub> emission coefficients of the different kinds of energy are constant and equal to the coefficients in 2010.

## 4. Results and Analyses

### 4.1. Carbon Emission per Tourist of Different Tourist Attractions

Based on the results of the questionnaire survey in conjunction with the results from the carbon emission measurement method used in Becken et al. [26] and Kuo and Chen [28], this paper arrives at the carbon emissions per tourist in the WHSIA as shown in Table 1. The results show there are great differences in carbon emissions per visitor across the different types of tourism attractions at the heritage tourist destination. The details are as follows:

First of all, the carbon emissions per visitor for the “museum” type (5.14 kg/p) is the highest. This is mainly due to the widespread use of photoelectric technology in the Chinese Giant Salamander Museum, which consumes more energy and produces more carbon dioxide emissions. On the other hand, the museum is a derivative tourist attraction and its attraction to tourists is very limited, which results in a small denominator of the number of tourist visits and, hence, higher carbon emissions per visitor. Secondly, the carbon emissions per visitor of the “tourism performance” and “cave sightseeing with light show” types are also relatively high, such as the Charming Xiangxi Performance at 1.54 kg/p and the Huanglong Cave Light Show at 1.35 kg/p. The Charming Xiangxi Performance consumes a large amount of energy to maintain the light show and first-class acoustic equipment while Huanglong Cave needs to operate electric boats and maintain various color lighting. Thirdly, even though the Wujiayu Sightseeing Spot, Tianzi Mountain, and other tourist attractions are of the “natural sightseeing” type, they do provide low-emission bus service, which contributes to the increase of carbon emissions of 1.24 kg/p albeit from the low-emission type of buses. The Ten-li Gallery Boutique Route provides sightseeing electric train service with an operating distance of 10 km so its carbon emission per tourist is also at a relatively high level at 1.25 kg/p. Fourthly, due to the short running distances of the Huangshizhai Cableway and Tianzi Mountain Cableway, the carbon emission per visitors is lower at 0.64 kg/p and 0.5 kg/p, respectively. Operating electric boats on Baofeng Lake also results in low carbon emissions per visitor (0.50 kg/p). The carbon emission per visitor at the “natural sightseeing” and “religious and cultural attractions” types are also lower.

In general, compared to the natural attractions, the use of photoelectric technology will significantly increase the carbon emissions of man-made tourist attractions. Besides, the carbon emission of different types of traffic tourist attractions varies greatly.

## 4.2. Evolution of Time Pattern of Carbon Emissions

### 4.2.1. Monthly Variation

We investigated the amount of carbon emissions of each tourist attraction in the WSHIA for each month of 2010 and 2014. The carbon emissions for each month as a percentage of the annual total are computed using the averages of the months in the two years as presented in Table 2.

**Table 2.** Monthly carbon emissions as a percentage of the annual total at each tourist attraction in the WSHIA.

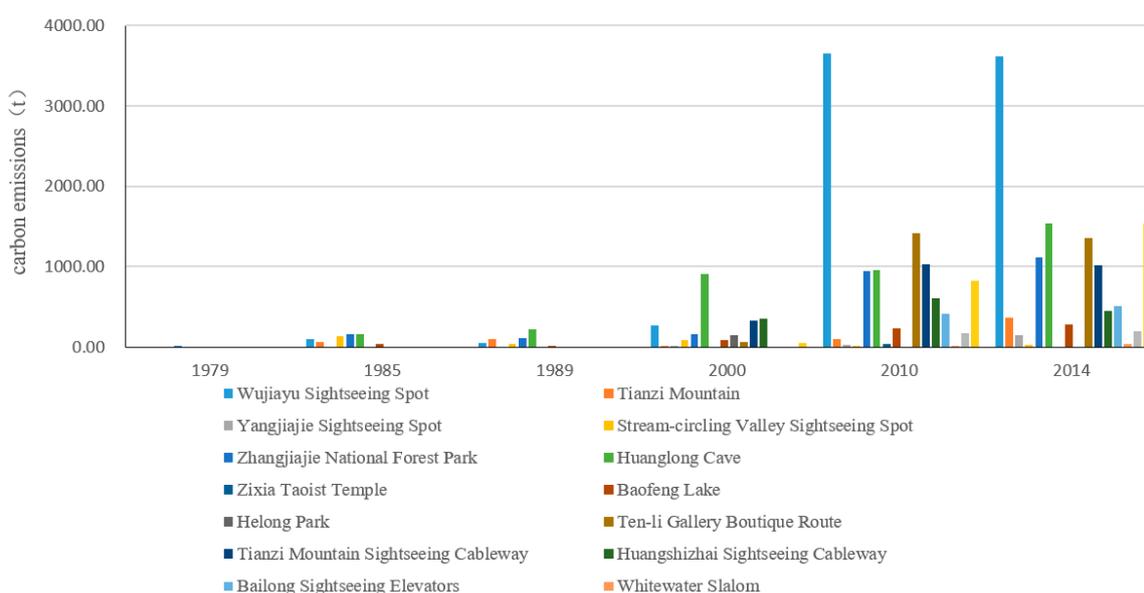
Tourist Attractions	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Std	CV (%)
Wujiayu Sightseeing Spot	1.03	3.94	4.81	13.26	11.17	8.19	13.49	13.91	8.81	12.37	6.22	2.81	4.54	54.46
Tianzi Mountain	0.86	2.78	1.79	5.43	8.12	8.30	16.74	24.43	8.33	14.93	5.19	3.10	7.06	84.74
Yangjiajie Sightseeing Spot	0.92	4.26	1.33	5.81	8.70	8.23	17.35	20.98	8.25	17.30	4.26	2.61	6.73	80.75
Stream-circling Valley Sightseeing Spot	1.87	7.79	4.61	11.14	11.56	7.08	10.36	13.55	7.23	16.92	4.30	3.61	4.48	53.76
Zhangjiajie National Forest Park	0.81	3.80	3.29	10.09	9.57	8.63	15.29	17.19	8.43	13.96	5.88	3.06	5.22	62.62
Huanglong Cave	1.31	3.88	4.19	10.31	9.57	7.84	15.69	16.26	8.92	13.17	6.34	2.53	4.96	59.49
Zixia Taoist Temple	0.40	0.17	4.74	13.04	12.17	8.03	16.00	15.47	9.51	12.47	6.48	1.53	5.70	68.39
Baofeng Lake	0.70	1.70	3.42	10.38	11.81	9.14	14.01	14.19	10.04	14.03	7.47	3.11	4.98	59.82
Ten-li Gallery Boutique Route	1.04	3.34	4.74	11.01	9.79	8.28	13.56	15.19	9.78	13.54	6.87	2.85	4.63	55.59
Tianzi Mountain Sightseeing Cableway	0.97	3.15	5.13	12.31	10.96	8.77	14.32	14.14	9.11	12.24	6.21	2.70	4.63	55.60
Huangshizhai Sightseeing Cableway	1.36	6.33	4.89	12.46	11.04	8.31	13.96	13.20	7.73	12.67	5.43	2.59	4.31	51.77
Bailong Sightseeing Elevators	1.23	5.16	4.69	11.55	9.63	8.39	13.37	14.83	9.02	12.66	6.47	3.01	4.31	51.74
Whitewater Slalom	0.00	0.00	0.00	0.00	0.00	42.34	52.42	5.24	0.00	0.00	0.00	0.00	18.43	221.11
China Giant Salamander Biotechnology Museum	4.70	5.61	10.11	9.05	9.94	9.70	11.69	12.27	9.00	6.93	5.71	5.30	2.59	31.13
Charming Xiangxi Performance	3.25	3.27	3.13	4.78	5.01	11.24	12.71	12.50	13.20	13.84	10.98	6.08	4.41	52.87

The results indicate that: (1) the monthly variation of carbon emission percentage of the tourist attractions is consistent with the tourism seasonality of the WSHIA. It varies greatly with an average value of 8.33% and a standard deviation of 4.88%, and the total percentage from April to October is 82.05% while the value between November to March is a relatively small amount of 17.95%. (2) The standard deviation of monthly carbon emissions in most tourist attractions is moderate at between 4.31% and 5.22%. It is between 5.70% and 7.06% in Tianzi Mountain, Yangjiajie and Zixia Taoist Temple. (3) The standard deviation of monthly carbon emissions in some tourist attractions is quite different from the others. The carbon emissions of China Giant Salamander Biotechnology Museum shows a small standard deviation of 2.59% due to the fact that museum tourism is an indoor tourism product and the seasonal variation is relatively small. The Whitewater Slalom is a summer tourism activity that mainly opens from June to August and has not yet been extended to the other months due to the low outdoor water temperature. Hence, the standard deviation of carbon emissions is larger. Therefore, we can see that the monthly variation of carbon emissions of different tourist attractions is roughly consistent.

### 4.2.2. Interannual Variations

Figure 2 shows the amount of carbon emissions of each tourist attraction in the WSHIA from 1979 to 2014. We have computed that: (1) the annual growth rate of carbon emissions from all tourist

attractions in the WSHIA from 1979 to 2014 is 25.49%. The CO<sub>2</sub> emission of all tourist attractions in 1979 was 5.42 t, and reached 12203.36 t by 2014. (2) The proportion of carbon emissions at all natural tourist attractions had remained dominant for a long time, changed from 100.00% in 1979 to 85.45% in 2014. Although man-made attractions built to attract tourists (such as the Charming Xiangxi Performance) have begun to develop in recent years, the pattern of carbon emissions dominated by natural sightseeing will persist long into the future. (3) There are great differences in carbon emissions among the tourist attractions. The Tianzi Mountain, Huanglong Cave, Ten-li Gallery Boutique Route, Tianzi Mountain Cableway, and Charming Xiangxi Performance account for 83.40% of the total carbon emissions in all tourist attractions in 2014 while all other attractions account for 16.60%. The large carbon emissions of these five tourist attractions are mainly due to the construction of cableways, low-emission buses, trams, electric boats, a large number of indoor lighting and audio, etc., that consume more energy.



**Figure 2.** Carbon emissions at tourist attractions in the WSHIA from 1979 to 2014.

#### 4.3. Evolution of Spatial Pattern of Carbon Emissions

##### 4.3.1. 1979–1989

The spatial pattern of carbon emissions has evolved from single scattered point to multiple scattered points. The tourist attractions of the WSHIA have been carrying out forest sightseeing activities in Zhangjiajie Forest Farm since 1979. Zhangjiajie Forest Farm became the first national forest park in China in September of 1982. The tourist attractions of the WSHIA were constructed after September of 1982. By 1989, a lot of tourist attractions had been built, such as the Zhangjiajie National Forest Park, Wujiayu Sightseeing Spot, Tianzi Mountain, Stream-circling Valley, Huanglong Cave, Baofeng Lake, etc. Carbon emissions from tourist attractions at the WSHIA increased from 5.42 t in 1979 to 516.36 t in 1989, with an annual growth rate of 65.91%. In terms of spatial pattern, it evolved from a single scattered point in 1979 (Zhangjiajie Forest Farm) to multiple scattered points in six tourist attractions in 1989, as shown in Figure 3.

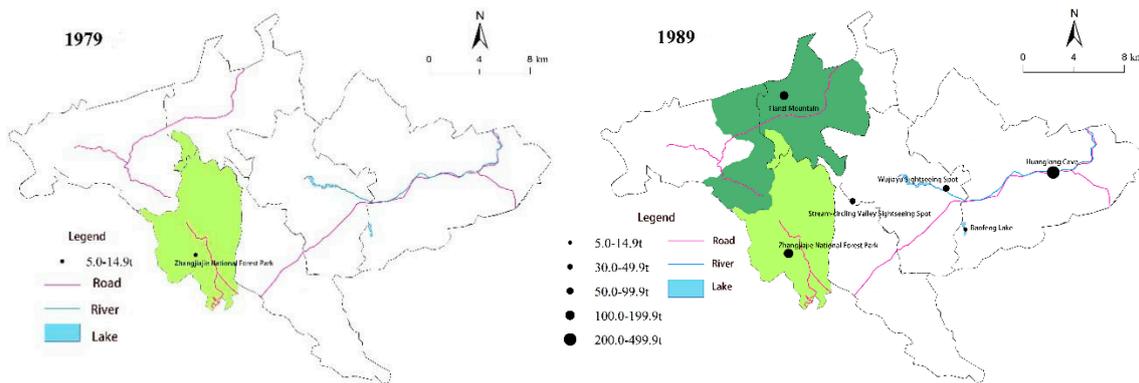


Figure 3. Spatial patterns of carbon emissions at tourist attractions in the WSHIA in 1979 and 1989.

#### 4.3.2. 1990–2000

The Wulingyuan District was established in May 1988. Establishment of the administrative system further promoted the construction and development of the tourist attractions at the WSHIA. The WSHIA was listed as World Natural Heritage in 1992, and Helong Park, a natural sightseeing spot, was further developed. Meanwhile, the Ten-mile Gallery Sightseeing Tram, Tianzi Mountain Cableway, and Huangshizhai Cableway, whose main function was sightseeing, had all been built and put into operation and the Charming Xiangxi Performance was also completed, forming twelve tourist attractions. Carbon emissions of tourist attractions at the WSHIA increased from 516.36 t in 1989 to 2462.31 t in 2000, with the annual growth rate declined to 16.91%. The characteristic of the spatial pattern of carbon emissions of tourist attractions at the WSHIA over this period demonstrates the combination of scatter points and group, which include the group of Wulingyuan Scenic and Historic Interest Area and scattered points such as the Baofeng Lake, Huanglong Carve, Charming Xiangxi Performance, and so on, as shown in Figure 4.

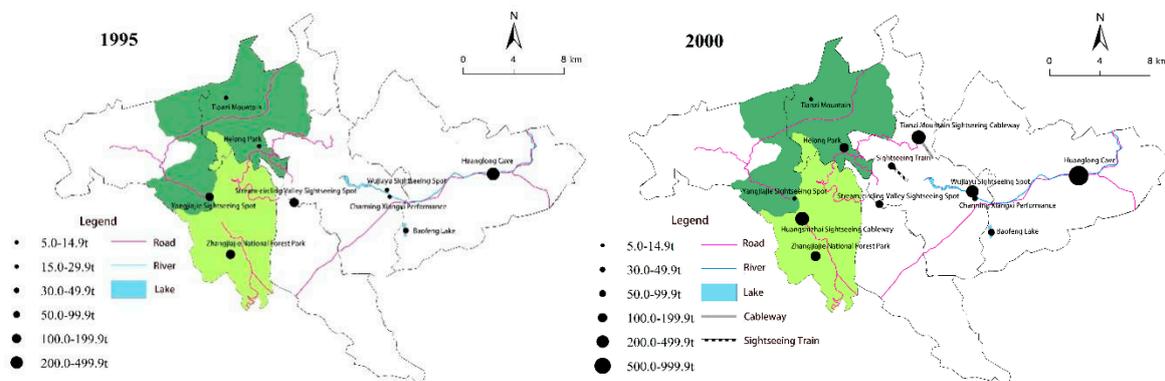


Figure 4. Spatial patterns of carbon emissions at tourist attractions in the WSHIA in 1995 and 2000.

#### 4.3.3. 2001–2014

The WSHIA was listed as the first batch of "World Geopark" in 2004 in China and the first national AAAAA scenic spot in 2007. The number of tourist attractions at the WSHIA increased from twelve in 2000 to fifteen in 2010 and fourteen in 2014. At this stage, some cultural performance tourist attractions appeared with fierce competitions in the market and encountered mergers after a few years. This paper chooses Charming Xiangxi Performing Stadium, which had developed gradually, as the representative. Carbon emissions of tourist attractions at the WSHIA increased from 2462.31 t in 2000 to 12,203.36 t in 2014, with an annual growth rate declined to 13.10%. The spatial pattern of carbon emissions of tourist attractions at the WSHIA is the combination of clustering and agglomeration, which includes the core tourist attraction groups of the WSHIA and all kinds of tourist

attraction agglomeration in the Wulingyuan town. The core tourist attraction groups of the WSHIA combine natural sightseeing and various modes of sightseeing transportation. The carbon emissions agglomeration areas in the Wulingyuan town include the Baofeng Lake, Zixia Taoist Temple, China Giant Salamander Biotechnology Museum, Charming Xiangxi Performance, Huanglong Cave, and other tourist attractions, as shown in Figure 5. With the increasing capacity of tourist attractions, the amount of tourist reception also increases, accompanied by the increasing carbon emissions of tourist attractions.

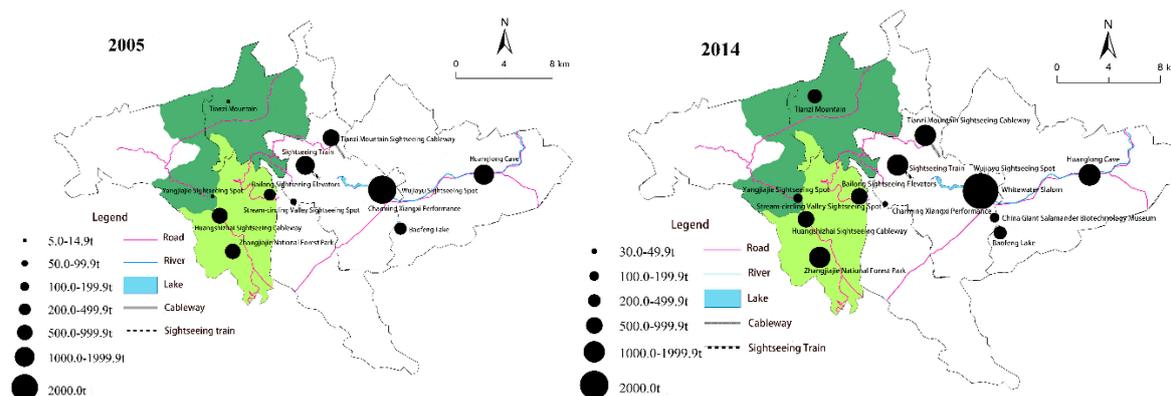


Figure 5. Spatial patterns of carbon emissions at tourist attractions in the WSHIA in 2005 and 2014.

#### 4.4. Factors Affecting the Evolution of the Spatial-Temporal Pattern of Carbon Emissions

##### 4.4.1. Factors Affecting the Evolution of the Temporal Pattern of Carbon Emissions

Tourism seasonality is a phenomenon of temporary imbalance of tourism, which mainly reflects the fluctuation of key factors such as the number of tourists, tourist expenditure, tourism traffic, tourism employment, tourist flow, etc. [62]. Seasonality directly causes the double fluctuation of tourism demand and supply. Due to the difference of off-peak season, scenic spots, tourism enterprises, and other tourism service providers will adjust the allocation of resources accordingly [63]. Generally, during the peak tourist season, the larger the number of tourists each tourist attraction needs to receive, the higher the carbon dioxide emissions will be. There are great monthly differences in carbon emissions among the tourist attractions at the WSHIA, with a coefficient of variation of 4.88%. The amount of carbon emissions of the tourist attractions between April to October as a percentage of the annual total was 82.05% with the remaining 17.95% occurred between November to March of the following year, which is consistent with the seasonality of the tourism in the WSHIA. Tourism seasonality is, therefore, an important factor affecting the monthly variation of carbon emissions at the tourist attractions in the WSHIA.

From the perspective of the tourism destination life cycle, the main factors affecting the quick increase of tourism carbon emissions are the rapid growth of tourist scale and tourism industry scale [15]. From 2000 to 2018, the annual growth rates of domestic and inbound tourists were 12.53% and 3.14%, respectively [64,65]. By 2018, the number of domestic tourists reached 5.54 billion and inbound tourists reached 141.2 million [65]. Furthermore, World Heritage is the most important tourist attraction across the world. As a result, many tourist destinations in China are committed to applying for the status of a World Heritage Site to promote the rapid development of the tourism industry. With the expansion of China's tourism market and the warming up of heritage tourism, tourist attractions at the WSHIA start to focus on the Wulingyuan Scenic and Historic Interest Area and strengthen the construction of tourist attractions. Huangshizhai Cableway, Bailong Sightseeing Elevator, Chinese Giant Salamander Science and Technology Museum, Charming Xiangxi Performance, and other tourist attractions have been built one after another. Therefore, the rapid growth of China's tourism market

and the continued popularity of heritage tourism are the external factors affecting the annual change of carbon emissions from tourist attractions at world heritage tourist sites.

#### 4.4.2. Factors Affecting the Evolution of the Spatial Pattern of Carbon Emissions

The WSHIA was listed as a World Natural Heritage in 1992. To protect the WSHIA effectively, the local government has scientifically compiled the Master Plan of the WSHIA. According to the different requirements of protection and utilization mode, the WSHIA is divided into the core area (specially protected area and first-class protected area), the buffer area, and the construction area. The scope and function of each area are divided and positioned, as shown in Table 3. Heritage protection and the development of tourist attractions are carried out strictly according to the functional division of the WSHIA. So the functional zoning of world heritage sites affects the spatial layout and evolution of tourist attractions, and in turn, affects the evolution of the carbon emission spatial pattern of tourist attractions at the heritage tourist sites.

**Table 3.** Functional zoning of the WSHIA.

Functional Zoning	Functional Sub-Region	Acreage	Basic Functions	Distribution of Tourist Attractions
Core Area	Specially protected area	9.8 km <sup>2</sup>	Resources are absolutely protected. Entry of personnel and any activities that change their natural appearance without the approval of the competent authorities are prohibited.	Not open to tourists
	First-class protected area	207.4 km <sup>2</sup>	Under the premise of strictly protecting natural heritage from damage, moderate scientific investigation and sightseeing activities can be carried out.	Wujiayu Sightseeing Spot, Tianzi Mountain, Yangjiajie Sightseeing Spot, Stream-circling Valley, Zhangjiajie National Forest Park, Helong Park, Huanglong Cave, Baofeng Lake Sightseeing Trams, Tianzi Mountain Cableway, Huangshizhai Cableway, Bailong Sightseeing Elevator
Buffer Area	No classification	174.0 km <sup>2</sup>	Agricultural and sideline production activities, outdoor recreation activities, tourism crafts processing, traditional family handicraft industry with local characteristics.	Zixia Taoist temple, China Giant Salamander Biotechnology Museum
Construction Area	No classification	6.3 km <sup>2</sup>	Tourist reception service facilities, tourism services and the production and living of local residents.	Charming Xiangxi Performance

Note: This form is derived from the Master Plan of the WSHIA.

Due to the lack of green development concept during the development of the WSHIA, a large number of illegal tourist reception facilities and excessive sewage discharge occurred in Zhangjiajie National Forest Park in the WSHIA in 1998. It was given a yellow card warning by the UNESCO. To maintain the outstanding universal value of the natural heritage site, the local government of the Wulingyuan District has taken a series of effective measures, including the demolition of illegal construction of hotels and residential areas that affect the outstanding universal value of the natural heritage site. Then, the local government of Wulingyuan District formulated the "Ecological Migration Compensation and Resettlement Scheme of Tianzishan Scenic Spot and Yuanjiajie Scenic Spot of the Wulingyuan Scenic and Historic Interest Area" and the "Core Scenic Spot Migration Production and Life Compensation Policy Plan" in 2018. These rectification measures and environmental regulations play an important role in the spatial evolution of carbon emissions of tourist attractions in the WSHIA.

The product system of heritage tourism in the WSHIA is developed based on tourism market demand and tourism resource endowment. The heritage tourism products have evolved from early forest eco-tourism to current diversified tourism products such as geological heritage tourism, lake

heritage eco-tourism, water conservancy eco-tourism, Taoist cultural tourism, Xiangxi ethnic culture performance, Chinese Giant Salamander Museum tourism, etc. In conclusion, the heritage tourism products of the WSHIA range from natural heritage to cultural heritage, from material heritage to intangible cultural heritage, and form a unique heritage tourism product system.

## 5. Discussion and Conclusions

### 5.1. Discussion

The United Nations World Tourism Organization (UNWTO) [66] defines sustainable tourism as “tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities”. Many scholars pay attention to the economic, ecological and social effects of sustainable tourism [67–69]. The carbon emission effect has become a hot spot for sustainable tourism research in recent years. Many scholars have studied the sustainable tourism development of different types of tourism destinations [68,70].

Since the 1970s, as one of the main forms of tourism, heritage tourism has made great progress around the world [71]. Heritage has become a core element of more than 40% of international travel [72]. In recent years, as China has stepped up efforts to promote ecological civilization, the coordinated development of heritage protection and tourism utilization has become one of the hot topics [73]. With the emergence of global climate change and energy security, green and low-carbon development of the tourism industry has become an important way for the sustainable development of heritage sites. Some scholars have performed research on the sustainable development of heritage tourism sites from the perspective of community participation [45], tourists’ behavior [74,75], and low carbon tourism products [75]. However, there are few studies on carbon emissions of tourist attractions at heritage tourist destinations currently [3,16,20,47]. Due to the varied factors of heritage protection, large-scale esthetic areas, enhancement of the quality of tourists’ experience, and increased tourism income, many heritage tourist destinations have developed different operational modes of tourism transportation. In WSHIA, there are traffic tour ways with local characteristics such as sightseeing by cableways, elevators, electric trains, electric boats, low-emission buses and so on. In addition, many tourist attractions such as Charming Xiangxi Performance and Huanglong Cave in the WSHIA have been developed. These have undoubtedly increased carbon emissions in the tourism industry of heritage sites, but also posed challenges to heritage protection, climate change, and energy security. In this paper, the aspect of carbon emissions from these tourist attractions is calculated and analyzed. This will enrich the research of the sustainable development of heritage tourism from the perspective of carbon emissions.

There are some studies on carbon emissions from tourist attractions and activities [26,28,50], and relatively few scholars have carried out research on this. In particular, there have been few reports on carbon emissions from tourist attractions and activities at heritage tourist destinations. The WSHIA is a world natural heritage site. After more than forty years of tourism development, the WSHIA has established a series of heritage tourist attractions. In this paper, according to the classification method of Swarbrooke [59] for tourist attraction, the tourist attractions of WSHIA are divided into three categories and eleven specific types. In reference to the carbon emissions of the three types of tourist attractions of Becken et al. [26] and Kuo and Chen [28], this paper estimates the carbon emissions from natural sightseeing, unpowered tourist aquatics, and religious cultural attractions at the WSHIA. Carbon emissions from other specific types of tourist attractions are calculated from the bottom-up using primary and secondary data sources. This research augments the lack of study on carbon emissions from tourist attractions at heritage tourist sites and enriches the existing studies on carbon emissions of various types of tourist attractions in destinations.

At present, there are two kinds of quantitative methods for measuring carbon emissions of different types of tourist attractions. The calculation method applied to analyze the energy consumption of tourist attractions at the destinations is a bottom-up method. This method calculates the carbon

emissions of each link of tourism step by step at the destinations. Becken et al. [26] calculate and analyze carbon emissions from tourist activities and entertainment of the tourism business sector in New Zealand. The estimation method is suitable for referencing the value of carbon emissions from other scholar's research results on similar tourist attractions. Angsumalin et al. [76] estimated carbon emissions of tourist transportation at Suan Phueng Mountain in Thailand. As the China Tourism Satellite account has yet to be formed, and the greenhouse gas emission monitoring system has yet to be systematically established, it is difficult to obtain continuous and available data of tourism carbon emissions. We have adopted a method combining calculation and estimation, but it still face some challenges. For instance, the estimation method may cause a certain degree of data bias, and the calculation method may make it difficult to collect energy consumption data of previous years.

Current research on carbon emissions in tourism can be divided into two dimensions: time and space. On the one hand, previous investigations on energy consumption and carbon emissions from the tourism industry focus on different spatial scales, such as the country level [8,77], the regional scale [11,78], the city level [12,13], islands [14,28], local national parks [19], and World Heritage Sites [3,15]. On the other hand, some scholars pay special attention to the carbon emissions over a certain period of tourist destination development [12,79] or the whole life cycle of tourist destinations [15]. However, there are only a few studies about the spatial evolution of carbon emissions in a tourism destination from the micro-scale measurement and perspective. This article fills this gap from the perspective of carbon emissions from tourist attractions at heritage tourist destinations.

## 5.2. Conclusions

Carbon emissions of tourist attractions play an important role in the sustainable development of tourism industry at heritage tourist destinations. The WSHIA, a natural heritage destination, is chosen as the case study. The carbon emissions from tourist attractions at the heritage tourist destination are measured and estimated using primary and secondary data sources for the period of 1979 to 2014. The characteristics of the temporal and spatial evolution of carbon emissions and its influencing factors for tourist attractions at heritage tourist destinations are analyzed. The conclusions are as follows:

- (1) There are great differences in carbon emissions per visitor across the different types of tourist attractions at the heritage tourist destination. In order to enhance the experience of the tourists, many operators utilize the optoelectronic technology heavily, and it will undoubtedly increase the energy consumption and carbon emission of tourist attractions. These operators have the responsibility to promote energy saving and emission reduction for the sustainable development of the heritage tourist destinations.
- (2) There are significant monthly differences in carbon emissions from tourist attractions consistent with the seasonality of tourism in the WSHIA. The seasonal variation of tourism flow and carbon emission should be considered in energy conservation and emission reduction of tourist attractions. From 1979 to 2014, the annual growth rate of carbon emissions of tourist attractions in the WSHIA was 25.49%. The amount of carbon emissions of natural tourist attractions as a percentage of the total amount remained dominant for an extended period in the WSHIA.
- (3) The spatial evolution of carbon emissions from tourist attractions in the WSHIA can be divided into three stages: from 1979 to 1989, the spatial pattern evolved from a single scatter point to multiple scatter points; from 1990 to 2000, the spatial pattern was characterized by the combination of clusters and scatter points; and from 2001 to 2014, the spatial pattern was characterized by the combination of clusters and agglomerations. On the basis of scientific treatment of the relationship of protection and development, the tourist attractions of heritage tourism sites are characterized by agglomeration, which will be conducive to energy conservation and emission reduction. This is beneficial to sustainable development in the heritage tourist sites.
- (4) The main factors affecting the evolution of the temporal pattern of carbon emissions from tourism attractions at world heritage sites are tourism seasonality, the rapid growth of China's tourism market, and the continuously expanding demand for heritage tourism. The main factors affecting

the spatial evolution of carbon emissions from tourism attractions at World Heritage Sites are functional zoning and environmental regulation of heritage sites and diversified evolution of heritage tourist attractions. From the perspective of time and space, these factors have different impacts on the carbon emissions of tourism attractions at heritage tourism destinations. How to quantify the impact of these factors on carbon emissions is worthy of in-depth study.

### 5.3. Policy Recommendations

Based on the above conclusions, we make a few suggestions for optimizing the spatial pattern of carbon emission in tourist attractions at the heritage tourist destination. On the one hand, the Master Plan for World Heritage Sites should be strictly implemented to effectively protect the outstanding and unique universal value of the heritage site. Tourist activities should be strictly prohibited and tourist attractions cannot be constructed within the super-grade nature reserves of the core heritage areas. Eco-tourism attractions can be constructed only in the first-grade nature reserves of the core heritage areas. Limited types of tourist attractions such as outdoor recreation and leisure agriculture can be built in the buffer zone of the heritage sites. Tourist attractions that require a large number of service facilities such as resorts, cultural and entertainment places, and others should be constrained within the construction area of the heritage sites.

On the other hand, according to the Energy Conservation Law of the People's Republic of China, energy and environmental policies and the manual of carbon management for the scenic spots should be formulated and implemented at heritage tourist destinations to promote energy conservation and reduce carbon emissions through laws and policies. The concept of green tourist consumption should be advocated and high-quality tourists traveling should be cultivated within and between heritage tourist destinations. The consumer behavior of tourists at the scenic spots should be guided by the concept of green consumption.

### 5.4. Limitations and Future Research Directions

Just as any case study, there are limitations in this study which in turn suggest further research. First, this study targets only the WSHIA. Future studies are needed to explore other heritage tourist destinations with other unique features to examine the differences of the temporal and spatial evolution of carbon emissions from the scenic spots in different types of heritage tourist destinations, such as cultural heritage tourism destinations. At the same time, there are also differences between urban and rural tourism destinations, such as traditional villages and historic conservation area, and the influencing factors of carbon emissions are also different, which is one of the research directions in the future. Second, due to the different enterprise operations of the studied subjects, the energy consumption data of natural eco-tourism tourist attractions and religious and cultural tourist attractions cannot be collected, leading to the inability to measure carbon emissions from these tourist attractions. As a result, we have to reference the result of Becken et al. [26] and Kuo and Chen [28] to estimate the carbon emissions from these tourist attractions. This may lead to undesired deviation in carbon emissions of these types of tourist attractions at the heritage tourist destination. Third, as the heritage tourism market continues to heat up, the energy consumption and carbon emissions of tourist attractions at heritage tourist destinations need to be constantly monitored and measured in future research. Therefore, it is very important to carry out energy conservation and emission reduction in tourist attractions on the premise of protecting the heritage. Fourth, an evaluation system on the carbon efficiency of tourist attractions at heritage tourist destinations should be constructed to identify which types of tourist attractions belong to green and low carbon scenic spots. Fifth, in 2018, the government of Wulingyuan District launched the revision of the General Plan of the WSHIA (2020–2040), which may have an important impact on heritage protection and the planning and construction of tourist attractions. The impact of this revised plan on the spatial pattern of carbon emissions should be further studied.

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