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Research Article

Analysis and Prediction of the Coupling Coordination Relationship between Tourism and Air Environment: Yangtze River Economic Zone in China as Example

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The results show that the comprehensive development degree (CDD) of the tourism-air environment system mainly maintains stable with fluctuation and the gap among different reaches in the Zone is declining; the coupling coordination degree's (CCD) tendency in most regions remains similar as in the previous decade. The results illustrate that the method combing information entropy weight and the technique for order preference by similarity to an ideal solution (IEW-TOPSIS), coupling coordination degree model (CCDM), and gray GM (1, 1) prediction model is effective in evaluating the coupling coordination relationship between the subsystems of tourism and air environment and in proposing specific countermeasures for tourism development and air environment governance.

1. Introduction

Tourism industry depends on the air environment to a large extent [1], and air environment has a complicated interaction with tourism development so that much concern has been caused [2–5]. The favorable air environment is playing a fundamental role in tourism development with sustainability and is also a marketing highlight in the local tourism industry so that it is mandatory and required to enhance the air environment quality of the tourism destinations [6]. Meanwhile, tourism has significant impacts on air environment: it brings both benefits and drawbacks to the air environment; if planned reasonably and organized scientifically, tourism will contribute to better air quality; otherwise, it may cause air pollution and other ecological related problems such as ecosystem services, biological communities' survivals, and biodiversity [7–9]. Considering the effects of tourism on the air environment is of significance due to the fact that the products and services of tourism mainly depend on the appeal and attractiveness of air-related natural resources, such as clean and fresh air and comfortable climate [10, 11]. Furthermore, tourism is also easy to be affected by the local negative air impacts, such as air pollution, fog, and haze [12, 13]. Therefore, it is necessary to explore useful approaches to support tourism development with sustainability, enhance the understanding of the coupling coordination between the two subsystems of tourism and the air environment, and sustain the quality of air environment at the satisfying status via such coordination.

By using the panel data of the Yangtze River economic zone (the Zone) of China between 2009 and 2018, this study firstly constructs the aggregated evaluation system for the coupling coordination relationship between tourism and air environment and calculates the weights of the indices within the evaluation system via the information entropy weight method (IEW) quantitatively and objectively, secondly uses the technique for order preference by similarity to an ideal solution (TOPSIS) and coupling coordination degree model (CCDM) to analyze the coupling coordination relationship between the two subsystems, and thirdly uses gray GM (1, 1) model to predict the future coupling coordination relationship of the system. This study aims at (1) discovering the comprehensive development degrees of the two subsystems of tourism and air environment in the Zone from 2009 to 2018, (2) exploring and predicting the dynamic coupling coordination development between the subsystems, and (3) proposing specific countermeasures for the tourism industry planning with sustainability and macroscopical air environmental policymaking.

Tourism is defined as individuals' activities of travelling to and accommodating in a certain place which is not the usual living environment for some time [14]. Tourism includes business sectors such as entertainment, cuisine, transportation, scenic spots, accommodation, tourism-related events, and travel trades [15]. Air environment, namely, atmospheric environment, in this study refers to the status where the function and the structure of the air environment are stable, robust, and comprehensive and are integrated to provide human activities with reliable air ecoservices [16]. Air environment reflects both the potential and risks of the ecological environment and human development. Both tourism and air environment have similarities to a degree such as sharing some of the same factors (e.g., transportation); nevertheless, they are different because tourism is a specific industry while air environment is an ecological system [17].

1.1. The Effects of Tourism on Air Environment. Tourism activities related to air environment have caused much focus these years. Research has proved that tourism development is related to air environment, and the tourism development can affect the air environment both positively and negatively via the indirect or direct approaches. From the perspective of negative impacts, increasing results have shown that tourism activities lead to pressure on the air environment. Tourism activities will inevitably arouse significant negative impacts on the air environment, such as air pollution [18, 19]. Furthermore, tourism activities contribute to the formation of the attitudes toward air environment [20]; in the tourism industry, the ethics toward the air environment determine the actions of balancing the relationship between tourism and air environment [21]. Besides, by emitting greenhouse gases through various tourism activities such as accommodation, transportation, entertainment, etc., tourism activities change the energy consumptions [22–25], which inevitably leads to the climate change and increases the burden of the air environment. There are two parts to evaluate the energy consumption for tourism activities, which are transportation-related tourism activities and destination-related tourism activities, respectively [19, 26], and both illustrate how the tourism affects the air environment. The negative effects on the air environment from tourism have been discussed in the areas worldwide, from developed countries such as Spain [27] to developing ones such as China [28] based on grounded theory, questionnaires, etc.

Meanwhile, some research studies also exhibit the benefits of air environment from tourism activities. Tourism stimulates air environmental changes in a positive way and also is affected by such changes [29]. For instance, 1% of increase in tourism revenue contributes to the 0.105% reduction of CO_2 emissions [30], and the developing countries have slower reduction speeds than the developed countries [31]. Furthermore, being considered as the low-carbon industry [32], tourism activities contribute to the upgrade of industrial structures and the renewal of urban functions, which helps better air environment protection [33, 34]. Cases from the regions characterized as the traditional manufacturing industry centers prove that tourism industry, as a new economy growth mode, contributes to restructuring of the urban functional structures and to the protection of the air environment [35, 36].

1.2. The Effects of Air Environment on Tourism. Growing research shows that air environment has impacts on tourism activities both negatively and positively. On the one hand, the air environment is increasingly and improperly utilized for tourism activities in certain tourism destinations, leading to the result that the tourism is negatively affected [37]. Concerns regarding the negative air environmental effects on tourism increase with the development of the tourism industry, including psychological discomfort after tourism [19], disease infection and diffusion [38], and tourists' dissatisfaction and negative word-of-mouth communications [39]. The air environment-related problems ruin the reputation and image of the tourism destinations, reduce the expectation and evaluation of the tourism activities from the tourists, and also hinder the tourism development with sustainability. Therefore, studies regarding sustainable tourism from the perspective air environment are carried out, such as tourism sustainability, tourism carrying capacity, low-carbon tourism, tourism environment quality with its measurement, and tourism environment protection [40–44].

On the contrary, tourism receives many benefits from the air environment improvement. The enhancement of the air environment provides abundant approaches for tourism development with sustainability. The air environment improvement is based on better environment-related infrastructure, the use of clean energy, adoption of air environmentally friendly technologies, better public transportation, and other services [17, 26, 45], which indirectly contributes to the development and performance of the tourism industry with sustainability. Besides, the benign image of air environment can increase the attractiveness and competitiveness of the local tourism. Favorable air environment could be illustrated as low pollution, clear air, and glamorous atmosphere [46]. Currently, some regions have initiated various programs aiming to enhance air environment and tourism attractiveness, and those places with good air environment conditions have become the popular and renowned tourism destinations [47]. For instance, Guiyang, the first city initiating the "national forest city" construction in China, highlights its tourism attractiveness as "natural oxygen bar" in the tourism marketing campaigns and now has become the popular and attractive tourism destination of the country. What is more, taxes from air environment governance provide benefits for less air pollution and further development of tourism business [48].

1.3. The Interaction between Tourism and Air Environment. It is obvious that the interaction between these two subsystems is intricate since there are several components in these two subsystems which dynamically change over time [49]. Coupling refers to the phenomenon where subsystems have effects on each other via interactions [50], so that it is a useful and applicable method to analyze the interaction dynamics of the subsystems of tourism and air environment. Guaranteeing the harmonious evolvement among subsystems, the coupling coordination degree (CCD) reflects the system's tendency to the orderly status, and it can be applied to trigger the positive interaction among the subsystems [1]. Research has been processed to measure the relationships of coupling coordination between the tourism subsystem and the general ecological environment subsystem in different places, such as Qinghai, Beijing, and Shaanxi [51–53], and shows that the coupling coordination between tourism and the environment is important theoretically and practically; however, studies are scant on the coupling coordination interaction between the tourism subsystem and the air environment subsystem.

There is great interest in tourism and the air environment in research; however, a more accurate, proper, and dynamic investigation of the coupling coordination relationship between the tourism and the air environment with sustainability is quite difficult considering that there is not a proper and widely accepted set of indices to measure such coupling relationship. Indices representing the air environment level are relatively scarce. Besides, previous research mainly focuses on the correlation between tourism and air environment, and there is lacking consensual research on the coupling coordination method and the interaction between these two subsystems. In addition, most research studies consider each region or place as a separate and independent individual, and ignore the spatial differences or comparisons among different regions. Therefore, it is needed to proceed more detailed research on the relationship of coupling coordination between tourism and air environment among different regions [54].

2. Study Area

The Yangtze River economic zone consists of 11 regions: Shanghai, Chongqing (2 municipalities), Anhui, Zhejiang, Jiangsu, Hubei, Jiangxi, Hunan, Yunnan, Sichuan, and Guizhou (9 provinces), with the land area accounting for about 21.4% in China. As the national strategic development area, it enjoys abundant tourism resources and strong industrial basis. It is rich in tourism resources: by the end of 2018, the numbers of the national nature reserves, wetland parks, forest parks, and the World Heritages accounted for more than 40% of the country, respectively. Besides, its population, the output value of the tertiary industry, and GDP also were over 40% of those in the country, respectively. However, the differences of tourism and air environment among regions in the Zone are obvious. Furthermore, its tourism industry is developing quickly; correspondingly, the impact of tourism on the air environment has been a serious problem for the sustainable development of tourism in the Zone. Therefore, selecting the 11 regions in the Zone as the objects is representative and significant to compare regional differences, facilitate the optimization of the tourism industrial structure, and promote the regional tourism growth and air environment governance with sustainability.

3. Materials and Methods

3.1. Evaluation Index System. There are complicated interactions between the two subsystems of tourism and air environment. Tourism can accelerate the effective and proper application of the air resources and can also damage the air environment via various tourism activities; the benign air environment can promote tourism development whereas the polluted air environment system may destroy the image of the local tourism and may impede the future development of tourism. Therefore, the system composed of the subsystems of tourism and air environment is regarded as a system of coupling coordination where the relationship of coupling coordination plays an important role in tourism development and air environment governance with sustainability [55]. The CCD can be measured so that an aggregated evaluation index system is constructed to measure the mutual effects of tourism and air environment. This study firstly selects indicators of the tourism-air environment system according to previous research studies [1, 14, 17, 26, 54, 56–62]. The selection and screening criteria include (1) covering and representing the components of tourism and air environment, (2) selecting the indices which are commonly referred and cited, (3) selecting the relatively simple and clear indicators in order to promote the effectiveness of collecting data and to enhance the index system dissemination and to eliminate multicollinearity, (4) reflecting the strategies or policies from the authorities, and (5) considering the accessibility of data [17, 58]. Secondly, the critical indicators were selected via the qualitative analysis and the comparisons of the correlation coefficients and the levels of significance so that the deeper understanding of the coupling relationship in the tourism-air environment system and the interactions among the subsystems can be explored. Thirdly, the evaluation index system, namely, tourism-air environment system composed of 2 subsystems (tourism and air environment), 5 dimensions, and 16 indicators, is constructed (Figure 1 and Table 1).

In the tourism subsystem, the dimension of Tourism Scale represents the integral size of the tourism industry, including the number of domestic tourists, the number of international tourists, the number of hotels, the number of travel agencies, and the number of employees of the tourism industry [1, 26, 58–61]; the dimension of Tourism Performance reflects the benefits and monetary status of the tourism industry, including earnings from domestic tourists and from international tourists [26, 58–60].

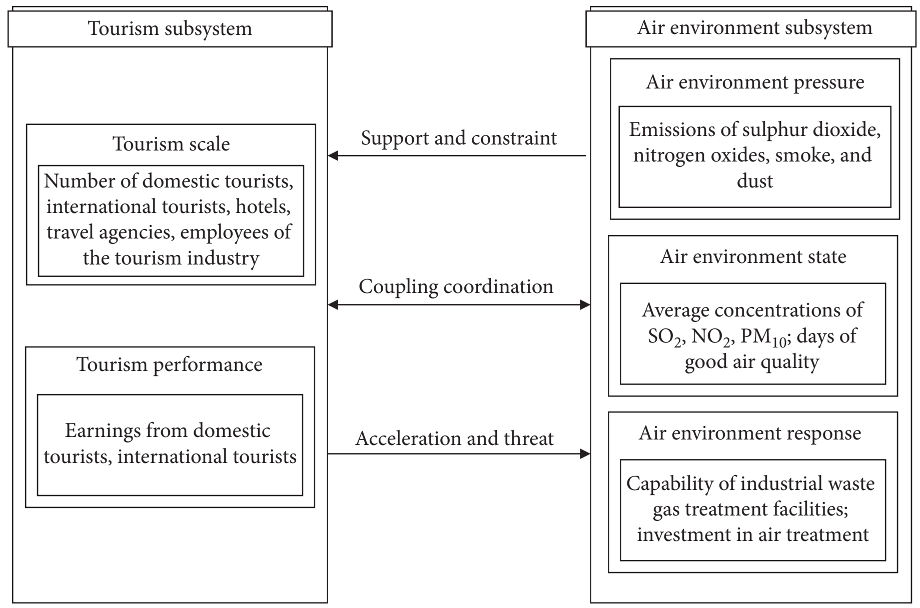

Figure 1: Coupling coordination relationship between the two subsystems.

Table 1: Evaluation index system of the two subsystems.

Subsystem	Dimension	Indicator	Interpretation
Tourism	Tourism scale (T_1)	Number of domestic tourists ($x_{1,+}$)[1]	Reflects the scale of domestic tourism
		Number of international tourists ($x_{2,+}$)	Reflects the scale of inbound tourism
		Number of hotels ($x_{3,+}$)	Reflects the scale of accommodation
		Number of travel agencies ($x_{4,+}$)	Reflects the scale of tourism services
		Number of employees of tourism industry ($x_{5,+}$)	Reflects the scale of people engaging in tourism services
	Tourism performance (T_2)	Earnings from domestic tourists ($x_{6,+}$)	Reflects the financial performance from domestic tourism
		Earnings from international tourists ($x_{7,+}$)	Reflects the financial performance from inbound tourism
Air environment	Air environment pressure (E_1)	Emissions of sulphur dioxide ($y_{1,-}$)	Reflects the pollution pressure from sulphur dioxide
		Emissions of nitrogen oxides ($y_{2,-}$)	Reflects the pollution pressure from nitrogen oxides
		Emissions of smoke and dust ($y_{3,-}$)	Reflects the pollution pressure from smoke and dust
	Air environment state (E_2)	Average concentrations of SO_2 ($y_{4,-}$)	Reflects the current status of SO_2
		Average concentrations of NO_2 ($y_{5,-}$)	Reflects the current status of NO_2
		Average concentrations of PM_{10} ($y_{6,-}$)	Reflects the current status of PM_{10}
		Days of good air quality ($y_{7,+}$)	Reflects the overall status of air environment
	Air environment response (E_3)	Capability of industrial waste gas treatment facilities ($y_{8,+}$)	Reflects the treatment degree of industrial waste gas
		Investment in atmospheric treatment ($y_{9,+}$)	Reflects the investment of air environmental pollution control

Note: "+" means the indicator is positive; "−" means the indicator is negative.

Regarding the air environment subsystem, the Pressure-State-Response (PSR) model, which is commonly applied to evaluate the environmental effects [2], is used to form the evaluation index system. The dimension of Air Environment Pressure reflects the pollution pressure of the air environment, including the emissions of sulphur dioxide, nitrogen oxides, smoke and dust [17, 54, 56, 57], etc. The dimension of Air Environment State reflects the development and the quality of the air environment, including the average concentrations of SO_2, NO_2, and PM_{10}, and the days of good air quality [14, 17, 54, 56, 62]. The dimension of Air Environment Response reflects the control and protection of the air environment, including the capability of industrial waste gas treatment facilities and investment in atmospheric treatment [17, 54, 56, 57, 62]. The tourism-air environment system is aggregated and hierarchical after indicator screening, with a detailed interpretation of the indicators in Table 1.

3.2. Data Collection and Preprocessing. The data in this study are from China Statistical Yearbook, China Statistical Yearbook on Environment, Yearbook of China Tourism, Yearbook of China Tourism Statistics, Yangtze River Yearbook, and so on from 2009 to 2018.

In the preprocessing procedure, the data are standardized with the following formula, if the indicator is a positive one, so that the differences of measurement units among indicators can be excluded, and the comparability among different indicators are valid. x_{ij} is the matrix X of the alternative i under indicator j among all the years:

$$x'_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}. \tag{1}$$

If the indicator is a negative one, the following formula is used for data standardization:

$$x'_{ij} = 1 - \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}, \tag{2}$$

$x' = (x'_{ij})_{m\times n}$ is the matrix after standardization of the range; $\max_{1\leq j\leq n} x_{ij}$ and $\min_{1\leq j\leq n} x_{ij}$ are the maximum value and the minimum value, respectively, in the indicator j among all the years.

3.3. Calculation of Tourism and Air Environment

3.3.1. Calculation of the Indicators' Weights. The information entropy weight method (IEW) has been utilized in research to evaluate the status uncertainty of the system; the larger value of the IEW represents the more balance of the system structure and the smaller variation, and vice versa. IEW can determine the index's weight by analyzing the correlation and information among the indices, which avoids the bias caused by subjective preferences and guarantees objectivity [63]. The evaluation steps are as follows:

(1) Calculate $\ln f_{ij}$ to avoid the insignificance:

$$f_{ij} = \frac{1 + x'_{ij}}{\sum_{i=1}^{m}\left(1 + X'_{ij}\right)}. \tag{3}$$

(2) Calculate the information entropy depending on the matrix $x' = (x'_{ij})_{m\times n}$:

$$H_j = -\left(\sum_{i=1}^{m} f_{ij} \ln f_{ij}\right), \quad i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n. \tag{4}$$

(3) Calculate the deviations in the coefficients of indices j (G_j):

$$G_j = 1 - H_j, \quad j = 1, 2, \ldots, m. \tag{5}$$

(4) Calculate the weight w_j of the indicator j. The data are not the same so that the indices are not seen as redundancies and the corresponding denominators will not be zero, and thus, the weights can be calculated:

$$w_j = \frac{G_j}{\sum_{j=1}^{n} G_j} = \frac{1 - H_j}{n - \sum_{j=1}^{n} H_j}. \tag{6}$$

3.3.2. Calculation of the Subsystems' Development Degree. The technique for order preference by similarity to an ideal solution (TOPSIS) is an improved approach; by using TOPSIS, the indicators' weights can be identified. TOPSIS reflects the relative importance of the indicators with the time sequences, which is more valid to evaluate the development degrees of the subsystems [64]. The steps are as follows:

(1) Determine the positive ideal solution and negative ideal solution, respectively. PIS X^+ and NIS X^- figure the most and the least preferred alternatives, respectively:

$$X^+ = \left(\max_{1\leq i\leq m} x_{i1}, \max_{1\leq i\leq m} x_{i2}, \ldots, \max_{1\leq i\leq m} x_{in}\right), \tag{7}$$

$$X^- = \left(\min_{1\leq i\leq m} x_{i1}, \min_{1\leq i\leq m} x_{i2}, \ldots, \min_{1\leq i\leq m} x_{in}\right). \tag{8}$$

(2) Calculate the separation measure from the NIS to PIS for alternatives:

$$d_i^+ = \sqrt{\sum_{j=1}^{n} w_j\left(x_{ij} - x_j^+\right)^2}, \quad i = 1, 2, \ldots, m;\ 0 \leq d_i^+ \leq 1, \tag{9}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} w_j\left(x_{ij} - x_j^-\right)^2}, \quad i = 1, 2, \ldots, m;\ 0 \leq d_i^- \leq 1. \tag{10}$$

(3) Calculate the relative closeness of the alternative to the ideal solution. c_i is the relative closeness in relation to the ideal solution of the i^{th} alternative and therefore named as the comprehensive development degree. The larger value the c_i is, the better development status of the subsystem is:

$$c_i = \frac{d_i^-}{d_i^+ + d_i^-}, \quad i = 1, 2, \ldots, m;\ 0 \leq c_i \leq 1. \tag{11}$$

(4) Establish the evaluation grade of the comprehensive development degree of each subsystem (CDD). Because the values of the CDD range from 0 to 1, the evaluation grade should be set up according to the concept of equalization. In detail, there are 4 grades: excellent ($c_i \geq 0.75$), good ($0.50 \leq c_i < 0.75$), fair ($0.25 \leq c_i < 0.50$), and poor ($c_i < 0.25$), which guarantees the equality of intervals and demonstrates the development status of the two subsystems objectively. The conversion is shown in Table 2.

Table 2: Evaluation grade of the comprehensive development degree.

Value	$c_i \geq 0.75$	$0.50 \leq c_i < 0.75$	$0.25 \leq c_i < 0.50$	$c_i < 0.25$
Grade	Excellent	Good	Fair	Poor

3.3.3. Calculation of the System's CCD. In this study, the coupling coordination system is composed of 2 subsystems (tourism subsystem and air environment subsystem), and they evolve each other or restrict each other coordinately. Coupling refers to the motion of the system where the subsystems interact with each other, and coordination refers to the relationship of subsystems which work together harmoniously [65]; the CCD represents the coupling coordination interactions of the subsystems [40].

(1) Calculate the coupling degree C of the system. $F(x)$ and $G(y)$ in the following equation are the comprehensive development degrees of the tourism subsystem and the air environment subsystem, respectively:

$$C = \left\{ \frac{F(x) \times G(y)}{((F(x) + G(y))/2)^2} \right\}^{1/2}. \tag{12}$$

(2) Calculate T, the comprehensive evaluation index of the tourism-air environment system. Here, α and β are the coefficients. After referring the existing research and the characters of the two subsystems, here we determine $\alpha = \beta = 0.5$ [66]:

$$T = \alpha F(x) + \beta G(y). \tag{13}$$

(3) Calculate the CCD of the tourism-air environment system D to measure the interaction between the two subsystems:

$$D = \sqrt{C \times T}. \tag{14}$$

According to the previous study [65], the classification for CCD is constructed (Table 3). Higher value of D represents better coupling coordination between the two subsystems of the year.

3.3.4. Prediction of the System's CCD. The gray prediction method, namely, GM (1, 1), is effective in predicting a system containing uncertain factors. It can make high-precision predictions with a small sample size [67]. The main principle of GM (1, 1) is to identify the different degrees of the trends among factors, generate raw data and find the laws, generate regular data sequences, establish differential equation models, and predict the system's trend.

(1) There are n observations in the original time series $X_0 = \{x_0(1), x_0(2), \ldots, x_0(n)\}$; the original sequence $x_1(t) = \sum_{i=1}^{t} x_0(i)$ is accumulated to generate the new sequence $X_1 = \{x_1(1), x_1(2), \ldots, x_1(n)\}$. Calculate the differential equation:

$$\mu = \frac{\mathrm{d}x_1(t)}{\mathrm{d}t} + \alpha x_1(t), \tag{15}$$

α is the development gray value; μ is the endogenous control gray value.

(2) $\hat{a} = (\alpha/\mu)$ is the estimated parameter vector, and use the least square method to calculate $\hat{a} = (B^T B)^{-1} B^T Y$, where $B = [-Z_1(2), -Z_1(3), \ldots, -Z_1(n), 1, 1, \ldots, 1]^T$ and $Y = [x_0(2), \ldots, x_0(n)]^T$; solve the differential equation, and then we can get the cumulative sequence prediction model:

$$\hat{x}(t+1) = \left[x_0(1) - \frac{\mu}{\alpha} \right] e^{-\alpha t} + \frac{\mu}{\alpha}, \quad t = 1, 2, \ldots, n. \tag{16}$$

If $0.3 < a \leq 0.5$, the data are valid to predict the short-term trend; if $a \leq 0.3$, the data are valid to predict the long- and medium-term trend. This is the most used indicator to test the model's accuracy [68].

Conduct the posterior error test and the residual error test to improve the accuracy of the prediction. Calculate the residual difference $\varepsilon_0(t)$:

$$\varepsilon_0(t) = x_0(t) - \hat{x}_0(t). \tag{17}$$

Calculate $q(t)$, relative error value of x_0:

$$q(t) = \frac{\varepsilon_0(t)}{x_0(t)} \times 100\%, \tag{18}$$

$\bar{\varepsilon}_0 = (1/(n-1)) \sum_{t=2}^{n} \varepsilon_0(t)$ is the mean of the residual $\varepsilon_0(t)$; $S_\varepsilon^2 = (1/(n-1)) \sum_{t=2}^{n} (\varepsilon_0(t) - \bar{\varepsilon}_0)^2$ is the variance of the residual $\varepsilon_0(t)$; $\bar{x}_0 = (1/(n-1)) \sum_{t=2}^{n} x_0(t)$ is the mean of the residual $x_0(t)$; and $S_x^2 = (1/(n-1)) \sum_{t=2}^{n} (x_0(t) - \bar{x}_0)^2$ is the variance of the residual $x_0(t)$. Calculate the variance ratio $C = S_\varepsilon / S_x$ and the small error probability $P = p(|\varepsilon_0(t) - \bar{\varepsilon}_0| < 0.6745 S_x)$. The test criteria for the accuracy are shown in Table 4, where the highest accuracy is defined as Grade 1 and the lowest accuracy is defined as Grade 4.

4. Results and Discussions

4.1. Analysis of the System's Comprehensive Development Degree. For the tourism subsystem, the comprehensive development degree (CDD) in the Zone calculated by IEW-TOPSIS is shown in Table 5. Generally, the CDD of tourism in the 11 regions is not high during 2009 and 2018, and the values fluctuated over time. There are three categories according to the evaluation grades corresponding to the mean values of CDD. The first category is "good" (0.50 to 0.75), including Shanghai, Jiangsu, and Zhejiang, which has a relatively high comprehensive development capacity in tourism. The second one is "fair" (0.25 to 0.50), which represents an acceptable comprehensive development capacity and which occupies over half of the regions including

Table 3: Evaluation classification for CCD.

Range	Value of D	Category
Coordinated (can be accepted)	$1 \geq D \geq 0.8$	Highly coordinated
	$0.8 \geq D \geq 0.7$	Intermediately coordinated
	$0.7 \geq D \geq 0.6$	Primarily coordinated
Transitional coordinated	$0.6 \geq D \geq 0.5$	Reluctantly coordinated
	$0.5 \geq D \geq 0.4$	Approaching imbalanced
Imbalanced (cannot be accepted)	$0.4 \geq D \geq 0.3$	Slightly imbalanced
	$0.3 \geq D \geq 0.2$	Moderately imbalanced
	$0.2 \geq D \geq 0$	Highly imbalanced

Table 4: Accuracy grade of the gray model.

Accuracy	r	C	P
Unqualified	<0.60	>0.80	<0.60
Grade 4	≥0.60	≤0.80	≥0.60
Grade 3	≥0.70	≤0.65	≥0.70
Grade 2	≥0.80	≤0.50	≥0.80
Grade 1	≥0.90	≤0.35	≥0.95

Anhui, Hubei, Hunan, Chongqing, Sichuan, and Yunnan. The third is “poor,” including Jiangxi and Guizhou and representing a low level of the comprehensive development in tourism with small increases over time.

The CDD of the air environment subsystem is shown in Table 6. Generally, the CDDs of air environment of the 11 regions are lower than those of tourism, and the fluctuations are much greater. The first category of “good” (0.50 to 0.75) contains Jiangsu only, which is two fewer than that in the “good” category of the tourism subsystem. Specifically, the CDD of Jiangsu in air environment subsystem showed a fluctuating trend: from fair (2009–2012) to excellent (2013–2016), then dropped to fair again (2017–2018). Shanghai, Anhui, Zhejiang, Hubei, Jiangxi, Hunan, Yunnan, Sichuan, and Guizhou fall into fair category with an acceptable comprehensive development level of air environment. Among them, Shanghai witnessed a declining trend of the CDD whereas Anhui maintained a general increasing trend. The third category, Grade “poor” (0 to 0.25), includes Chongqing only. It is mainly stable at a relatively low comprehensive development status with slight rises during these years.

The average values of the CDD of the two subsystems in the 11 regions of the Zone from 2009 to 2018 are visualized, respectively (Figure 2), in order to compare the geographical distribution status clearly. The CDDs of both tourism and air environment subsystems share similarities in geography: the lower reaches (Shanghai, Zhejiang, and Jiangsu) enjoy relatively higher CDDs compared with the middle and upper ones. In tourism subsystem, places in the lower reaches have higher CDDs due to the geographical advantage, abundant tourism resources, advanced transportation and infrastructure, scientific management, etc., and Jiangsu has higher CDD of air environment than the upper and middle reaches’ regions due to the strong air environmental investment and governance. On the contrary, in the subsystem of tourism, Guizhou, located in the upper reach of the Zone, has lower CDD because of the geographical drawbacks, poor transportation and facilities, relatively fewer tourism resources, lower society development, etc. In the subsystem of air environment, Chongqing, also located in the upper reach, has lower CDD due to the relative deficiency in air environment governance and investment. The differences between the two subsystems in other regions are not quite significant, which mainly fall into the “fair” grade of the comprehensive development.

4.2. Spatial-Temporal Analysis of the System’s CCD. The Zone’s CCDs of the tourism-air environment system are shown in Table 7, and the evolution trend reflecting the coupling coordination development over time is shown in Figure 3. Temporally, the coordination degrees of the tourism-air environment system coupling of the 11 regions of the Zone kept fluctuating between 2009 and 2018: most regions maintained the rise in fluctuation with the direction of benign coordination, whereas certain regions had downward trends. In specific, Shanghai, Jiangsu, Zhejiang, Anhui, and Hubei kept relatively high degrees of coupling coordination (above 0.6), which proved that these regions maintained an acceptable coordinated development status. Among them, Anhui had a leapfrog development with the status from reluctant coordination (0.501) to intermediate coordination (0.730) during 2009 and 2018, achieving 3 levels of span; however, it was also noticed that Shanghai and Jiangsu had declining trends, proving that the coordination and development of the two regions witnessed a deteriorative potential, and countermeasures are required to enhance the coupling coordination and to prevent further degenerations. Besides, Jiangxi, Hunan, Chongqing, Sichuan, and Yunnan remained fluctuating between the reluctant coordination (0.4 to 0.5) and approaching imbalance (0.5 to 0.6), which demonstrated that the coupling coordination of the tourism-air environment system of these regions was in the transitional development period this decade and the trend was much benign. Furthermore, though consistently stood at the lowest position in the degree of coupling coordination, Guizhou was enhancing its development status gradually: its degree of coupling coordination increased from moderate imbalance (0.212) in 2009 to approaching imbalance (0.479) in 2017, though decreased to slight imbalance (0.375) in the later 2018.

Table 5: CDD of the tourism subsystem.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean	Grade
Shanghai	0.952	0.689	0.732	0.702	0.631	0.664	0.653	0.611	0.657	0.662	0.695	Good
Chongqing	0.213	0.238	0.243	0.286	0.298	0.306	0.306	0.302	0.323	0.344	0.286	Fair
Anhui	0.215	0.286	0.284	0.347	0.370	0.392	0.398	0.407	0.430	0.455	0.359	Fair
Zhejiang	0.551	0.637	0.601	0.682	0.702	0.758	0.750	0.770	0.535	0.562	0.655	Good
Jiangsu	0.650	0.721	0.669	0.865	0.877	0.531	0.561	0.553	0.584	0.603	0.661	Good
Hubei	0.213	0.299	0.301	0.329	0.344	0.368	0.370	0.382	0.399	0.411	0.342	Fair
Jiangxi	0.146	0.223	0.204	0.219	0.218	0.233	0.256	0.257	0.278	0.289	0.232	Poor
Hunan	0.254	0.314	0.311	0.330	0.310	0.318	0.336	0.328	0.351	0.378	0.323	Fair
Yunnan	0.322	0.373	0.346	0.380	0.391	0.433	0.425	0.435	0.480	0.515	0.410	Fair
Sichuan	0.086	0.270	0.255	0.295	0.311	0.331	0.339	0.361	0.396	0.400	0.304	Fair
Guizhou	0.008	0.077	0.090	0.089	0.096	0.121	0.133	0.150	0.200	0.241	0.121	Poor

Table 6: Comprehensive development degree of air environment subsystem.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean	Grade
Shanghai	0.381	0.371	0.297	0.179	0.310	0.148	0.328	0.282	0.377	0.237	0.291	Fair
Chongqing	0.290	0.303	0.240	0.141	0.180	0.336	0.154	0.165	0.319	0.302	0.243	Poor
Anhui	0.293	0.567	0.537	0.169	0.455	0.543	0.344	0.496	0.661	0.858	0.492	Fair
Zhejiang	0.187	0.377	0.238	0.190	0.601	0.515	0.616	0.646	0.574	0.315	0.426	Fair
Jiangsu	0.427	0.470	0.354	0.451	0.805	0.851	0.785	0.818	0.475	0.322	0.576	Good
Hubei	0.245	0.575	0.510	0.158	0.385	0.436	0.482	0.366	0.492	0.433	0.408	Fair
Jiangxi	0.189	0.333	0.264	0.132	0.221	0.338	0.471	0.322	0.331	0.282	0.288	Fair
Hunan	0.288	0.399	0.361	0.221	0.390	0.349	0.380	0.310	0.278	0.315	0.329	Fair
Yunnan	0.259	0.469	0.337	0.823	0.302	0.319	0.411	0.408	0.250	0.247	0.382	Fair
Sichuan	0.732	0.322	0.311	0.269	0.313	0.399	0.331	0.222	0.166	0.287	0.335	Fair
Guizhou	0.243	0.304	0.259	0.207	0.400	0.336	0.389	0.359	0.264	0.082	0.284	Fair

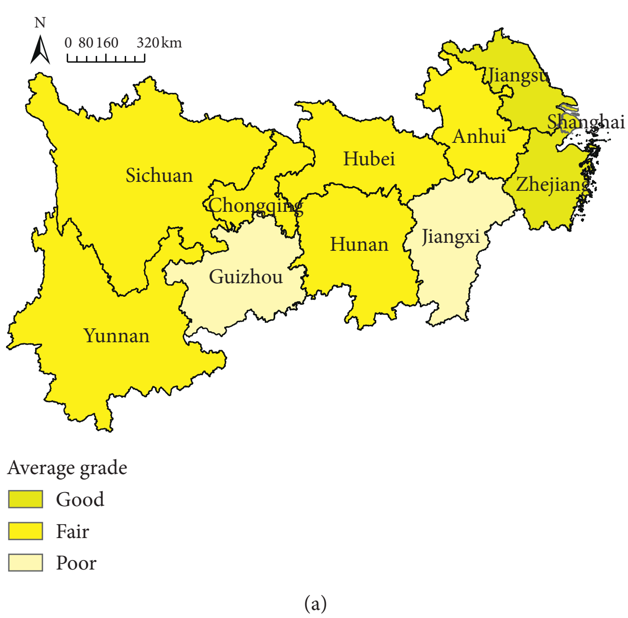

Figure 2: Geographical distribution of the average CDD. (a) Distribution of the tourism subsystem and (b) distribution of the air environment subsystem.

The visualization of the CCDs of the 11 regions in the Zone between 2009 and 2018 by ArcGIS 10.2 is shown in Figure 4 to measure the dynamic changes of the geographical distributions. It could be found that the coupling coordination development in the lower reaches is the highest while that of the upper reaches of the Zone is the lowest. In specific, the four regions (Shanghai, Jiangsu, Zhejiang, and Anhui) in the lower reaches, namely,

Table 7: CCDs of tourism-air environment system.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Shanghai	0.776	0.711	0.683	0.596	0.665	0.560	0.680	0.644	0.705	0.630
Chongqing	0.499	0.518	0.492	0.448	0.482	0.566	0.466	0.473	0.567	0.567
Anhui	0.501	0.635	0.625	0.492	0.641	0.679	0.609	0.670	0.730	0.791
Zhejiang	0.566	0.700	0.615	0.600	0.806	0.791	0.824	0.840	0.744	0.649
Jiangsu	0.726	0.763	0.698	0.790	0.917	0.820	0.815	0.820	0.726	0.664
Hubei	0.478	0.644	0.626	0.478	0.603	0.633	0.650	0.611	0.666	0.649
Jiangxi	0.407	0.522	0.482	0.412	0.468	0.529	0.589	0.536	0.551	0.534
Hunan	0.520	0.595	0.579	0.519	0.590	0.577	0.598	0.565	0.559	0.588
Yunnan	0.537	0.647	0.585	0.748	0.586	0.610	0.646	0.649	0.588	0.597
Sichuan	0.501	0.543	0.531	0.531	0.559	0.603	0.579	0.532	0.506	0.582
Guizhou	0.212	0.391	0.391	0.368	0.443	0.449	0.477	0.482	0.479	0.375

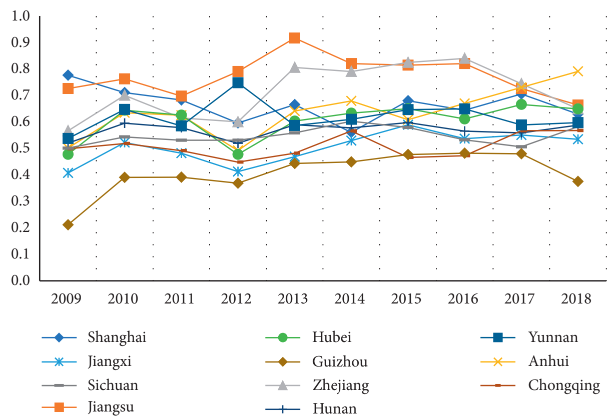

Figure 3: Evolution trend of the system's CCD.

Yangtze River Delta regions, kept a high status of coupling coordination development in the decade (mostly above 0.6) due to the lower pollutant emissions, enhanced investment in waste gas treatment, large numbers of visitors, geographical advantages, well-developed tourism facilities, resources, and industry, etc. Besides, the regions in the middle reaches (Hubei, Jiangxi, and Hunan) mainly maintained a relatively stable status in the past decade. Though there was an improvement of the coupled development, the effect is not quite apparent. The coupling coordination development of the middle reaches was weaker than the lower reaches while better than the upper ones. What is more, for the regions in the upper reaches (Sichuan, Chongqing, Guizhou, and Yunnan), the tourism-air environment CCDs showed an upward trend, which mainly maintained at the status of reluctant coordination (0.5 to 0.6), and gap of the degrees of coupling coordination between the upper reaches and the rest reaches was declining. This trend was mainly due to the scientific tourism resource planning and development, initiating tourism marketing campaigns and emphasizing air environment protection. Specifically, with the strategies of Poverty Alleviation through Tourism and Blue Sky Protection Campaign in the recent years, the 4 regions in the upper reaches implemented and received benefits from the related policies so that the gap of the system's CCD narrowed compared with the middle and the lower reaches.

4.3. Prediction of the CCD. This study used GM (1, 1) prediction model to predict the tendency of the CCDs of the tourism-air environment system for the 11 regions of the Zone, with the results shown in Table 8. In the accuracy test of the model, the estimated parameter, which is the most used to test the accuracy [68], $a < 0.3$, and the correlation degree $r > 0.6$, demonstrating that the model meets the requirement and is applicable for prediction. Moreover, most data meet the posterior error ratio $C \leq 0.8$ and the small error possibility $P \geq 0.60$, meaning that this model reaches a certain accuracy and can be used for prediction [68].

It can be found that the CCD's trend (year 2019–2021) of tourism-air environment system of the 11 regions in the Zone will largely remain the similar changing tendency as in the former decade. Specifically, for the regions with coordinated development (above 0.6), Shanghai and Jiangsu will continue the slight decline of the CCDs; Zhejiang and Anhui will continue to rise the CCDs, and both regions will transit from primary coordination (0.6 to 0.7) to intermediate coordination (0.7 to 0.8); Hubei will continue the fluctuation at the primary coordination status. Besides, for the regions with the status of transitional development (0.4 to 0.6), most of them will keep the trend of the slow development with fluctuation. The exception is Yunnan, which will face a slight decline in the degree of coupling coordination, though it will still stay in the same classification. Apparently, this is not a good sign for this traditionally touristy province and detailed countermeasures should be taken. What is more, Guizhou will continue staying at the lowest position among the 11 regions; meanwhile, it continues developing its CCD in the previous status of approaching imbalance (0.4 to 0.5).

For the tourism-air environment system of the Zone, the general tendency of the coupling coordination development is upward in the following 3 years, while the detailed direction of the tendency and the development speed varies among different regions. What is more, the spatial differences and gaps within the Zone will be narrowed. The coordinated development of the whole Zone requires every region to explore and eliminate the main restrictions, to carry out applicable regulations and policies, to cooperatively implement air environmental governance, and to develop the tourism resources and industry accordingly.

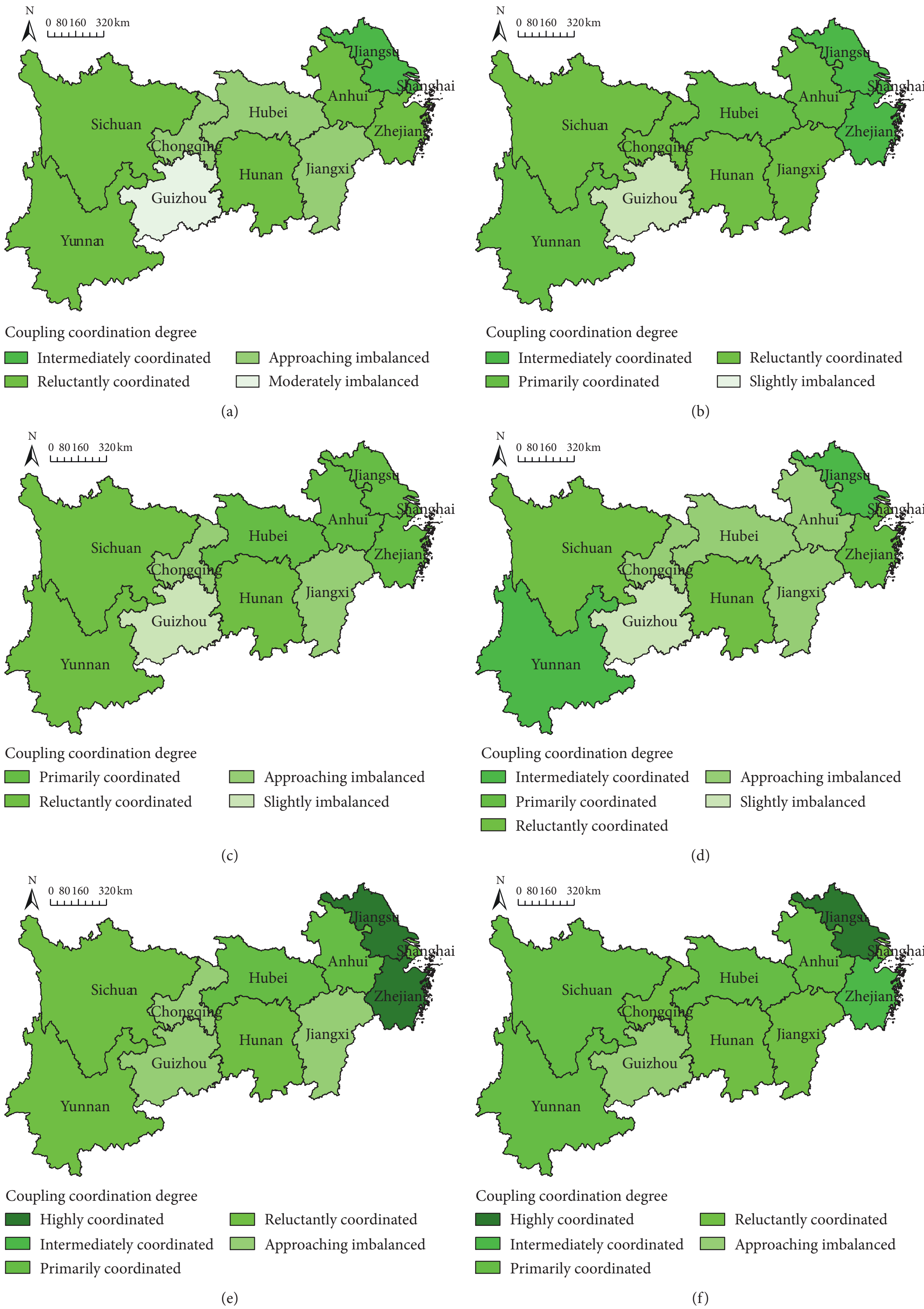

Figure 4: Continued.

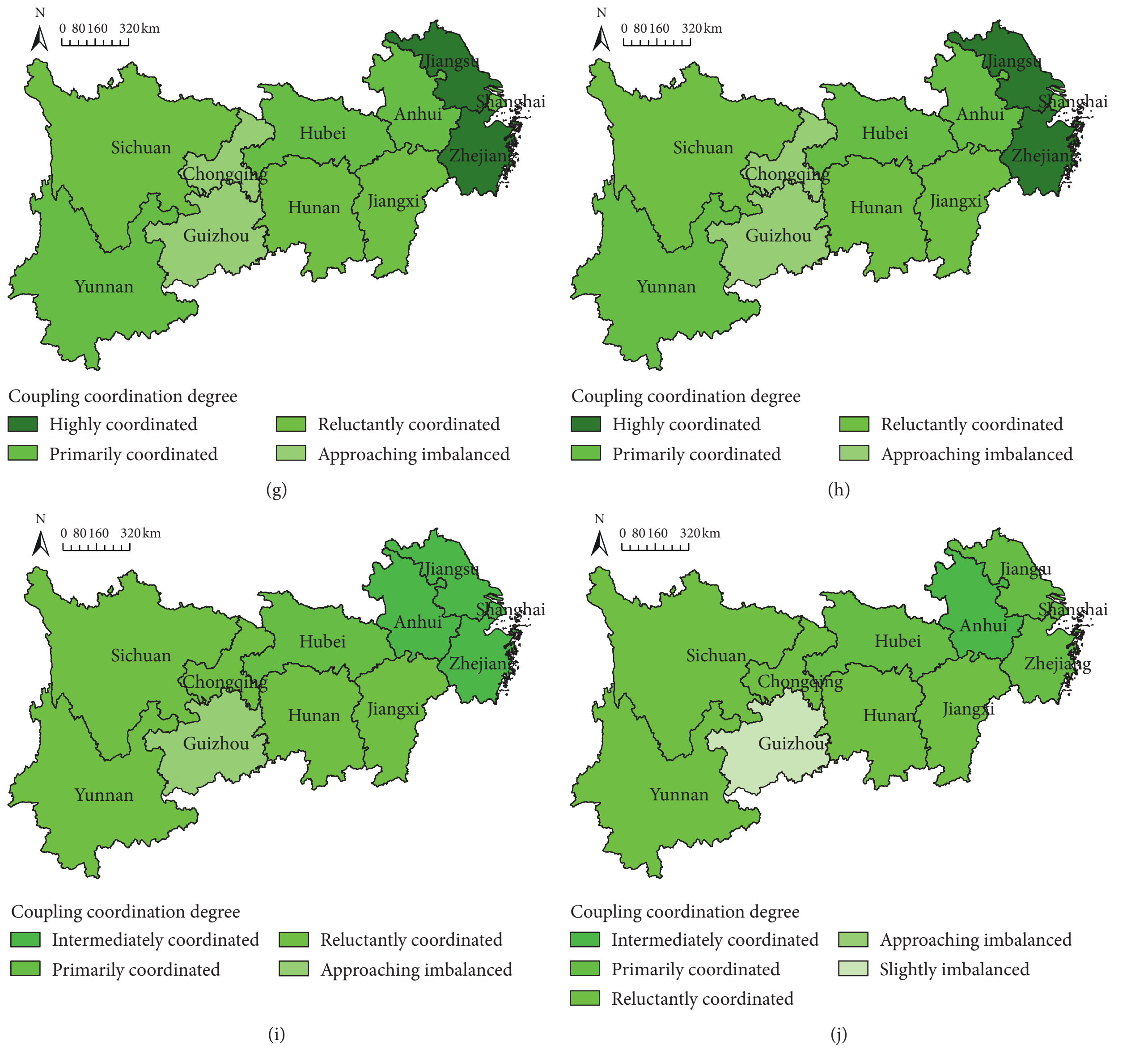

Figure 4: Geographical distributions of the CCD. (a) 2009; (b) 2010; (c) 2011; (d) 2012; (e) 2013; (f) 2014; (g) 2015; (h) 2016; (i) 2017; (j) 2018.

Table 8: Prediction of the CCD of tourism-air environment system.

	a	r	C	P	Prediction year		
					2019	2020	2021
Shanghai	0.004	1.085	0.766	0.600	0.640	0.638	0.636
Chongqing	−0.015	1.085	0.894	0.400	0.549	0.557	0.566
Anhui	−0.034	0.834	0.600	0.700	0.769	0.795	0.822
Zhejiang	−0.015	0.816	0.812	0.400	0.785	0.796	0.808
Jiangsu	0.007	0.598	0.953	0.600	0.752	0.746	0.741
Hubei	−0.013	0.876	0.711	0.800	0.657	0.666	0.674
Jiangxi	−0.020	0.767	0.688	0.700	0.568	0.580	0.592
Hunan	0.000	1.182	0.800	0.700	0.575	0.575	0.575
Yunnan	0.009	0.887	0.828	0.700	0.602	0.597	0.592
Sichuan	−0.003	1.102	0.867	0.500	0.560	0.562	0.564
Guizhou	−0.017	−2.379	0.489	0.900	0.466	0.474	0.482

5. Countermeasures

The coordinated coupling of tourism and air environment in the different regions in the Yangtze River economic zone has obvious spatial differences: the CCD of the upper reaches is lower than that of the lower reaches. Therefore, sustainable and coordinated tourism development and air environment governance are important and inevitable for the regions of the Yangtze River Economy Zone. Related participants should carefully evaluate and monitor the coupling factors between tourism and air environment. What is more, governors should enhance the air environmental quality by decreasing air environment pollution and waste gas emission and develop tourism with innovative minds. Based on this, this study proposes the following countermeasures specifically.

For the lower reaches' regions with a high CCD between tourism and air environment but with a declining trend for certain regions, they should upgrade the tourism industry structure, maintain a high status of coupling coordination based on air environment protection, and prevent the future declining. Specifically, they can (1) strengthen interregional tourism cooperation and realize spillover effects on the middle and upper reaches in terms of tourism and air environment governance and (2) make full use of the air environment and explore new tourism resources and develop new tourism methods (e.g., ecotourism and low-carbon tourism) so that the tendency of declining could be prevented and the tourism industry's growth and the air environment's governance with sustainability can be achieved.

For the middle reaches' regions where the CCDs remain stable, they should strengthen innovation and endeavor enhancing the coordination between tourism and air environment. Specifically, they can (1) continue the innovation and structural reform of the management and governance mechanism and exert the market's role and vitality in tourism and air environmental protection, so that the coordination between tourism business and air environment governance can be promoted, and (2) integrate air environment governance into the tourism industry development and effectively use tourism's positive function in the air environmental protection, so that the sustainable coupling coordination development of the two subsystems could be realized.

For the upper reaches' regions which are limited and lagging in tourism resources and air environment governance, they should vigorously accelerate tourism development and air environment governance. Specifically, they can (1) make use of national strategies and policies to develop tourism industry with local characteristics, to better control air environment pollution and to invest air environment governance, and to promote the leap-forward and coordinated development, and (2) use the latest technology to reduce the consumption of air environment resources and to enhance the efficiency of tourism industry, and reply on the cooperation with other reaches of the Zone to establish a new model of economy growth, and to build air environmental friendly societies.

6. Conclusions and Future Expectations

This study explores the coupling coordination development between tourism and air environment with the example of the Yangtze River economic zone between 2009 and 2018 by the approaches of IEW-TOPSIS method, coupling coordination degree model, and gray GM (1, 1) model. The conclusions are as follows:

(1) Generally, within this Zone, the comprehensive development degree of tourism is higher than the degree of air environment, and both maintain at the fair status with fluctuation over time.

(2) Temporally speaking, the CCD of the tourism-air environment system in the Zone mainly maintains stable with fluctuation. Most regions maintain the rise in fluctuation with the direction of benign coordination, whereas certain regions have downward trends. Besides, the gap of the coordinated development of tourism-air environment coupling between the upper reaches and the lower reaches is declining from 2009 to 2018.

(3) The prediction of the coupling coordination development shows that most regions will remain the similar changing tendency as in the previous decade and will improve the CCDs in the coming three years, while the speed is somehow slow. Great efforts are needed in order to realize coordinated development between the two subsystems in the Zone, which requires each region to take corresponding specific countermeasures to monitor the coupling factors and achieve coupling coordination development between the two subsystems.

The main contributions of this research include the following:

(1) This study considers factors relating to the development of tourism and air environment and constructs an aggregated evaluation system where the indicators are associated with the goals of tourism development and air environment governance. The system provides an effective reference for objective analysis and for the regulation of the coupling coordination relationship in public administration procedures.

(2) With the characters of complexity and systematisms of the tourism-air environment system, IEW-TOPSIS and CCDM have been important tools to discover the interaction among factors and can measure the coupling coordination temporally and spatially. This study selects the Yangtze River economic zone as the case, combines IEW-TOPSIS and CCDM, and investigates the coupling coordination between tourism and air environment, which breaks limitations of the former research which mainly focuses on a single region (city or province) without interregional comparisons.

(3) The prediction, made by the gray GM (1, 1) model, of the sustainable development of tourism-air environment coordination for the next three years will help authorities to understand relationship of coupling coordination development between tourism and air environment and to explore the primary factors leading to the temporal and spatial differences in coupling coordination development; furthermore, the prediction provides reference for local authorities to adjust the economic structure, develop tourism industry, and enhance air environment governance accordingly.

There are certain limitations of this study, for instance, this study mainly considers indices which are measurable and available while ignores some indicators which are difficult to evaluate due to the accessibility issue of statistical data, though it is obvious that the evaluation indices system should be multidimensional and comprehensive. Thus, this problem needs to be further analyzed in the future.

Data Availability

Data are available if requested to the corresponding author.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

Y.G. conceptualized the study, contributed to methodology, prepared the original draft, and supervised the study and was responsible for project administration and funding acquisition; Z.W. and H.Z. developed the software; Z.W. validated the data, performed analysis and data curation, investigated the study, and reviewed and edited the manuscript and was responsible for resources; Z.W. and M.M. were involved in visualization.

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