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To cite this article: Yiming Liu *et al* 2023 *Environ. Res. Lett.* **18** 014004

ENVIRONMENTAL RESEARCH
LETTERS

CrossMark

OPEN ACCESS

RECEIVED
5 August 2022

REVISED
2 November 2022

ACCEPTED FOR PUBLICATION
22 November 2022

PUBLISHED
15 December 2022

LETTER

Spatial and temporal changes in the coupling of ecological environment and tourism development: the case of Kyushu, Japan

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Keywords: ecological environment, tourism development, membership degree model, CCDM model

Abstract

The relationship between the ecological environment and tourism development is extremely complex. Summarizing evolutionary trends, temporal patterns and spatial differences in time and space can contribute to the coordinated development of an ecological environment and tourism. Based on the Carrying capacity–Supporting capability–Attraction capability–Evolutional capability–Development capability model and the Pressure–State–Response model, this paper proposes a conceptual index system using the entropy weight method and the coupled coordination degree model. The coupling coordination relationship between the ecological environment and tourism development in seven prefectures in the Kyushu region of Japan from 2010 to 2019 was analyzed. Then, using the membership degree model, the coordinated development of each prefecture was further analyzed. The results mainly show that in the Kyushu region, the degree of coupling coordination between the ecological environment and the tourism development system changed from moderate coordination to marginal coordination during the study period, then steadily improved, with large differences between regions. Based on the analysis results, this paper puts forward specific suggestions for the prefectures with lagging tourism development and lagging ecological environment development, respectively, to provide a reference path for the sustainable development of the ecological environment and tourism in the Kyushu region. For prefectures in the ecological environment development lag-type stage, the following requirements were identified: (a) the need for the government to strengthen tourism infrastructures; (b) the need for the government to focus on developing regional ecotourism, focusing on the fragility of island ecosystems and the sustainability of resources in the Kyushu region; (c) the need for the government to scientifically formulate tourism-related policies and plan tourism-related investments. For prefectures in the tourism development lag-type stage, the following were identified: (a) the need for the government to develop a variety of tourism products and create regional tourism brands based on local conditions; (b) prefectures should determine the main tourism functions and themes it offers based on the specifics of their resource advantages.

1. Introduction

As one of the world's largest economic industries, sustainable tourism has become a key policy objective for all countries [1, 2]. Tourism is a resource environment-dependent industry, and its unique attributes make its development contradictory to, yet unified with, the environment [3]. The rational use of the ecological environment by humans for tourism development can promote local economic development [4]. However, if overdeveloped, tourism can not only lead to deterioration of the ecological environment but also reduced related economic and social benefits [5–7]. Therefore, it is of high theoretical significance and practical value to study the coupling and coordination between tourism and the ecological environment.

Research into the contradictions between tourism and the ecological environment mainly focuses on the carrying capacity of the tourism environment [8, 9], the impact of tourism activities on the environment [10, 11], tourism ecological evaluation [12, 13] and tourism destination management [14, 15]. While promoting local economic development and increasing employment opportunities, tourism also creates issues such as biodiversity reduction [16, 17], accelerated soil erosion [18, 19] and solid waste pollution [20, 21]. It is self-evident that with the rapid development of tourism, pressures on the environment also increase. In studies related to tourism and the environment, findings indicate that tourism can contribute to the protection of the environment, but also have a negative impact on tourism destinations [22–24]. It is clear, therefore, that while over-development of tourism brings it into conflict with environmental protection, at the same time, tourism and the environment are interdependent.

Coupling refers to a measurable relationship between two or more systems that interact with each other [25]. The coupling coordination degree model (CCDM) is a tool to reflect the intensity of cooperative development based on the degree of coupling, and has been widely used in empirical applications [26–28]. The CCDM model has been extended across varying dimensions in research, and offers a new perspective on analyzing problems between multiple systems [29–31]; it has been applied to different fields, such as mathematics, geography and sociology [32–34]. These studies have examined the coupling relationships at national [35] and provincial scales [36, 37], and analyzed the spatial–temporal coupling between the tourism economy, the tourism industry and the environment.

From the above literature review, it was surmised that existing research on the coupled coordination of tourism and the environment is more concerned with large cities, the mature level of tourism development and one-way impacts of tourism on the environment, and that it ignores small and medium-sized cities as the basic units. This insufficiency thus generates a research priority to use small regions with immature tourism development as the subject of studies. In this respect, the Kyushu region of Japan was chosen as fitting these criteria, owing to its rich forest resources and valuable historical sites along with the presence of issues such as an aging population, industrial decline, and pressures regarding environmental protection. This makes the Kyushu region of Japan an important and valuable research target. In addition, current research on coupling coordination fails to explain the problem of sudden changes in boundary values. Since fuzzy mathematical theory can better solve this problem, this study introduces it to the study of coupling coordination for the first time. This study is expected to provide a point of scientific reference for the sustainable development of the tourism industry and ecological environment in small and medium-sized regions.

2. Study area

The Kyushu region is located at the southwesternmost tip of mainland Japan. It consists of eight prefectures: Fukuoka, Nagasaki, Saga, Oita, Kumamoto, Miyazaki, Kagoshima and Okinawa. Recently, tourism has become one of the key pillar industries of the region, and allied with the growing tourism economy is the risk for the ecological environment. Based on the availability of data for this study, data for the relevant ten-year period (2010–2019) from seven prefectures in the Kyushu region of Japan were used in this study: Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki and Kagoshima (figure 1).

3. Data and research methods

3.1. Index system and data source

The degree of coupling and coordinated development reveals the extent of closeness between systems, as well as the processes and extent of the development of other factors related to or caused by certain aspects [38–40]. The tourism industry itself is notable in terms of the extent of its various characteristics and systems, which leads to extremely complex interactions between its development and the ecological environment [41]. Therefore, constructing a scientific evaluation index system is the key. However, currently no unified standard exists as a basis for constructing an index for the coupling relationship between tourism development and the ecological environment.

Following the principles of data availability, indicator representativeness and system correlation, and referring to the results of previous research by the author [42], a conceptual indicator system for coupled and coordinated analysis of the ecological environment and tourism development was established. It contains two systems of ecological environment and tourism development, with eight subsystems and 27 indicators (as shown in table 1).

The data used in this study were mainly obtained from the Japanese Statistical Yearbook, the Statistics Bureau of the Ministry of Internal Affairs and Communications of Japan, the Ministry of Health and Labor of Japan, the Ministry of Land, Infrastructure and Transport of Japan, the Forestry Agency of Japan, and the Japan Tourism Agency. In addition, this study involved consultations with the relevant authorities by telephone to obtain data not provided in government-published yearbooks or bulletins. The calculation of data that were missing made use of the average interpolation method.

3.2. Method of evaluating development index

3.2.1. Standardization

Since the dimensions of each index differ, this study needed to standardize the initial values of each index.

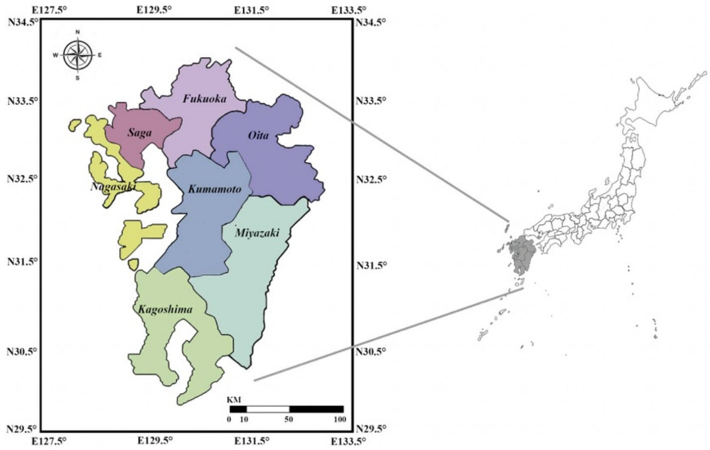

Figure 1. Location of Kyushu in Japan.

Table 1. Indicators of the two subsystems.

Subsystem	First-class index (F)	Second-class index (S)	Unit
Ecological environment (E)	Pressure (F1)	Waste emissions (GHG) (S1)	Thousand tons
		Exhaust emissions (S2)	Tons
		Power consumption (S3)	10^6 kWh
		Extent of natural disaster damage (S4)	Places
	State (F2)	Forest cover rate (S5)	%
		Nature reserves as a percentage of total area (S6)	%
		Park area per capita (S7)	m/people
		Arable land per capita (S8)	m/people
	Response (F3)	Waste disposal rate (S9)	%
		Sewage treatment rate (S10)	%
		Waste disposal rate (S11)	%
		Culture building expenditure as a percentage of total expenditure (S12)	%
Tourism development system (T)	Carrying capacity (F4)	Tourism spatial density (S13)	people/m^2
		Number of visitors received per day (S14)	Thousands of people
		Tourists as a percentage of the local population (S15)	%
	Supporting capability (F5)	Number of hotels (S16)	Places
		Density of road network (S17)	km/km^2
		Number of restaurants (S18)	Places
	Attraction capability (F6)	Number of attractions (S19)	Places
		Number of festivals (S20)	Places
		Number of cultural monuments (S21)	Places
	Evolutional capability (F7)	Per capita income (S22)	Million yen/people
		Urban construction expenditure as a percentage of total spending (S23)	%
		Tourism spending as a percentage of total spending (S24)	%
	Development capability (F8)	Tourism economic density (S25)	Ten thousand yen km^{-2}
		Tourism revenue as a percentage of GDP (S26)	%
		Accommodation and catering operating income (S27)	Ten thousand yen

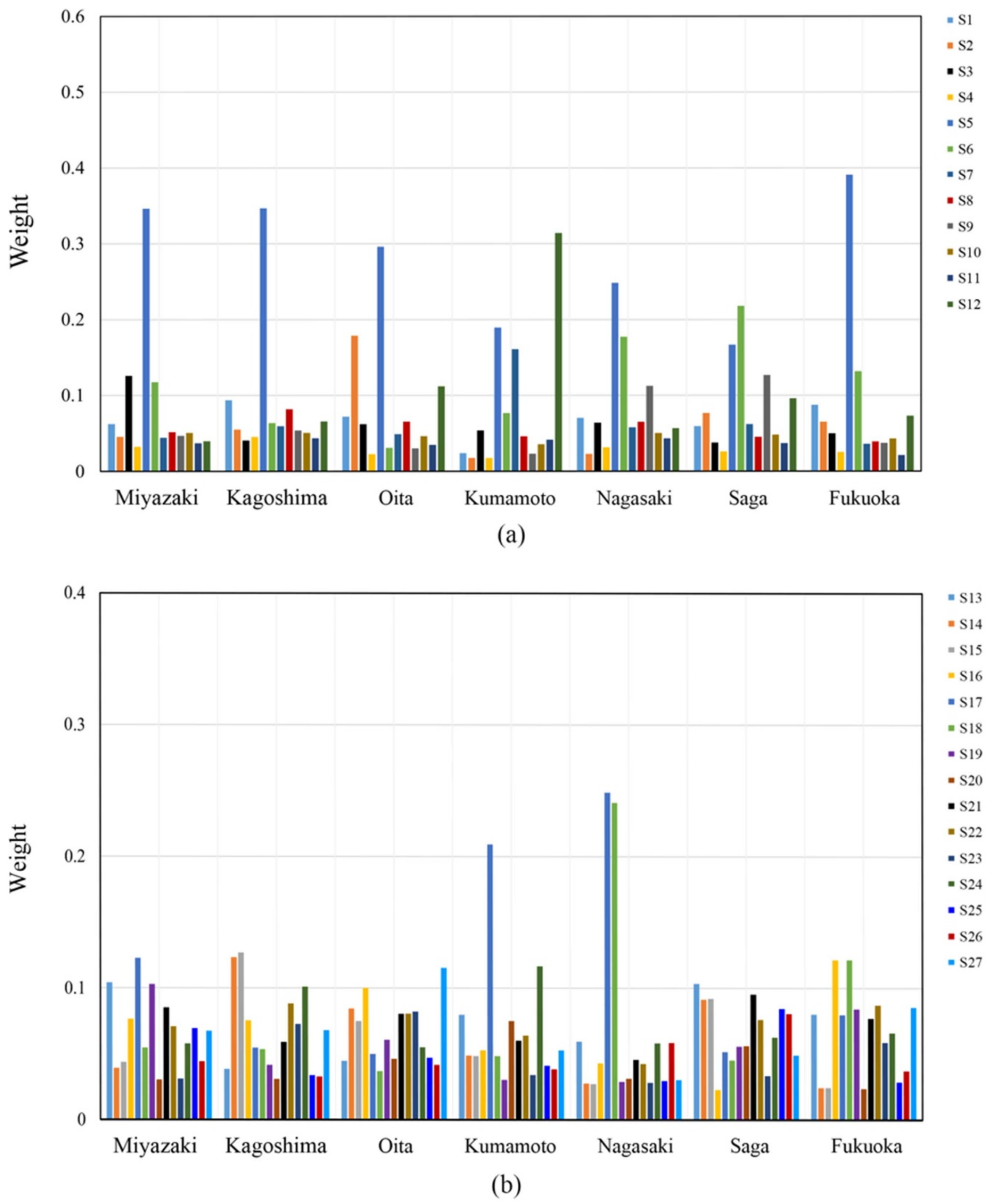

Figure 2. Weight of each index: (a) tourism; (b) environment.

Assuming that the mth index value of the nth year in a certain place is x_{nm}, the maximum value of index j is $x_{\max}$ and the minimum value is $x_{\min}$. The normalized value of x_{nm} can thus be obtained based on the positive and negative properties of the index.

Positive index (larger value for a useful parameter):

$$x'_{nm} = \frac{x_{nm} - x_{\min}}{x_{\max} - x_{\min}}. \tag{1}$$

Negative index (smaller value for a useful parameter):

$$x'_{nm} = \frac{x_{\max} - x_{nm}}{x_{\max} - x_{\min}} \tag{2}$$

where $n = 1, 2, \ldots, n$, represents the number of years, and $m = 1, 2, \ldots, m$, represents the number of indicators.

3.2.2. Weighting

Since the entropy weight method (EWM) is more objective than the subjective analysis method, this

Table 2. Classification table of coupling coordination degree.

Serial number	Range of coupling coordination	Coordination level
1	0.00–0.09	Extreme imbalance
2	0.10–0.19	Serious imbalance
3	0.20–0.29	Moderate imbalance
4	0.30–0.39	Mild imbalance
5	0.40–0.49	Near imbalance
6	0.50–0.59	Marginal coordination
7	0.60–0.69	Elementary coordination
8	0.70–0.79	Moderate coordination
9	0.80–0.89	Good coordination
10	0.90–1.00	Superior coordination

study uses the EWM to determine the weight of the index and avoid the influence of subjective factors. The EWM refers to using the information carried by the entropy value to calculate the weight, combining the degree of variation of each index, using the information entropy tool to calculate the weight of each index, and providing a basis for comprehensive evaluation of multiple indicators [43, 44]. This study follows the sequence of calculations used in the entropy method: calculation of the normalized index proportion S_{nm} of index m (equation (3)); calculation of the entropy value h_m of index m (equation (4)); calculation of the difference coefficient α_m of index m (equation (5)); and finally, determination of the weight of the indicator w_m (equation (6)). The weight of each index is shown in table 1 and figure 2:

$$S_{nm} = x'_{nm} / \sum_{n=1}^{p} x_{nm} \tag{3}$$

$$h_m = -\frac{1}{\ln p} \sum_{n=1}^{p} x_{nm} \tag{4}$$

$$\alpha_m = 1 - h_m \tag{5}$$

$$w_m = \alpha_m / \sum_{m=1}^{q} \alpha_m. \tag{6}$$

3.2.3. Calculating the subsystem development index

This study uses the weighting method to calculate the development level index P_n of a certain subsystem in a certain place in year i:

$$P_n = \sum_{m=1}^{q} w_m x'_{mn}. \tag{7}$$

This study made use of the CCDM to quantitatively measure the coupling coordination relationship between tourism development and the eco-environment. This tool, which is derived from the capacity coupling coefficient model used in physics, is notable in its ability to describe the factors that mutually influence or lead to synergy between different systems, thus revealing the degree of system linkage [45]. This model has been used in numerous research fields, such as economics [27], geography [29], biology [46] and tourism [47]. Therefore, based on existing results, this study involved constructing a coupled coordination model that can reflect the level of synergistic development of tourism and the ecological environment. The coupling coordination model is formulated as follows:

$$D(P_{\mathrm{TE}}, P_{\mathrm{EE}}) = \sqrt{C \times T} \tag{8}$$

$$C = \sqrt{\frac{P_{\mathrm{TE}} \times P_{\mathrm{EE}}}{(P_{\mathrm{TE}} + P_{\mathrm{EE}})^2}} \tag{9}$$

$$T = \alpha P_{\mathrm{TE}} + \beta P_{\mathrm{EE}} \tag{10}$$

where D denotes the degree of coupling coordination; C is the coupling degree of the two systems—wherein the larger the value of C, the higher the coupling degree—of which the value range is 0–1; T is the comprehensive coordination index of the two systems; TS and ES are the comprehensive evaluation indicators of the tourism development system and the ecological environment system, respectively; and α and β are undetermined coefficients. Since the tourism economic system and the ecological environment system are of equal importance, 0.5 was used for the value of α and β in the actual calculations of this research.

3.3. Classification of coupling coordination evaluation

To more objectively reflect the degree of coupling and coordination between systems, this study adopts the mean distribution function—a ten-point method used to classify the degree of coupling and coordination between two systems (table 2).

3.4. Membership model

It is well known that the classification of zones is crucial for determining the degree of coupling coordination, and various hierarchical classifications can be

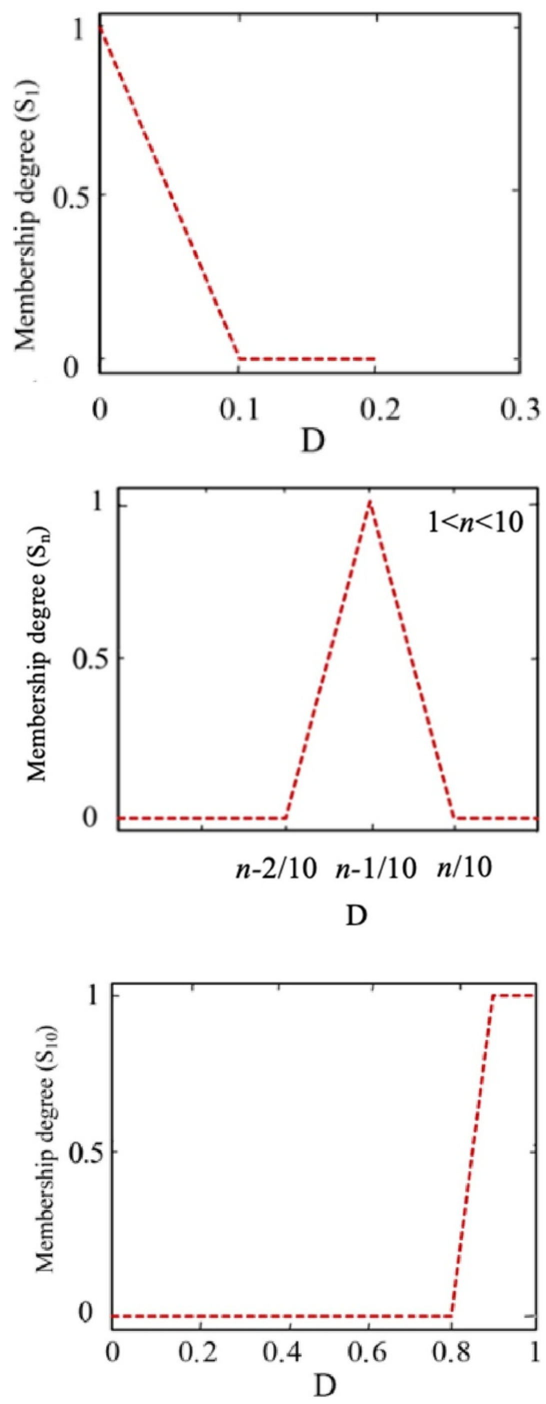

Figure 3. Membership function.

found in existing studies to analyze the degree of coupling coordination concerning the actual development of target areas [48, 49]. Such studies, however, fail to account for the problem of sudden changes in boundary values. The concept of membership was introduced in 1965 by the American automatic control expert Professor L A Zadeh, and was proposed to quantitatively describe fuzzy objects [50]. The advantage of the membership degree theory of fuzzy mathematics is its ability to transform qualitative aspects of evaluation into quantitative forms, to solve the fuzzy and difficult-to-quantify boundary value problem [51]. The membership model plays a role in associating evaluation elements and evaluation grades in the process of fuzzy evaluation, so the correct selection or construction of membership functions is key to the effect of comprehensive evaluation [52]. Therefore, considering the actual situation of the ecological environment and tourism development in the Kyushu region of Japan, this study uses the positive quantitative index membership function (11–13) to determine the coupling coordination degree, the membership function of which is shown in figure 3.

$$s_1(x) = \begin{cases} 1, \ x \leqslant 0 \\ 1 - 10x, \ 0 \leqslant 10x \leqslant 0.1 \\ 0, \ x \geqslant 0.1 \end{cases} \tag{11}$$

$$s_n(x) = \begin{cases} 0, \ x \leqslant \dfrac{n-2}{10} \\ 10x - n + 2, \ \dfrac{n-2}{10} \leqslant 10x \leqslant \dfrac{n-1}{10} \\ n - 10x, \ \dfrac{n-1}{10} \leqslant x \leqslant \dfrac{n}{10} \\ 0, \ x \geqslant \dfrac{n}{10} \end{cases}, \ 1 < n < 9 \tag{12}$$

$$s_{10}(x) = \begin{cases} 0, \ x \leqslant 0 \\ 10x - 9, \ 0.9 \leqslant 10x \leqslant 1 \\ 1, \ x \geqslant 1 \end{cases}. \tag{13}$$

4. Results and discussions

4.1. Changes in two subsystem indices

The development of subsystem indicators for ecological environment and tourism development in the Kyushu region of Japan is shown in figure 4, in which figure 4(a) shows the development trend of the ecological environment in the Kyushu region. From 2010 to 2016, the ecological environmental index was generally low in all seven prefectures, being less than 0.4. At the same time, the frequency of fluctuations was generally low. While four prefectures—Saga, Nagasaki, Oita and Fukuoka—maintained a relatively stable increase in their ecological environmental indices between 2016 and 2019, the other three prefectures showed a linear upward trend. Among them, Kumamoto, Miyazaki and Kagoshima showed relatively rapid increases in the ecological environmental index. In particular, the ecological environment indicators of Kumamoto Prefecture changed from the lowest (0.06) to the highest (0.81) among the seven prefectures, which was caused by the S12 indicator in the Response (F3) in the first-level indicator (F), which means that it was mainly owing to the prefecture's high budgetary allocation to cultural development. Development of the ecological environment in the remaining five counties also increased, but at a relatively slower pace, ranging from 0.15 to 0.29. Combined with the analysis of the index

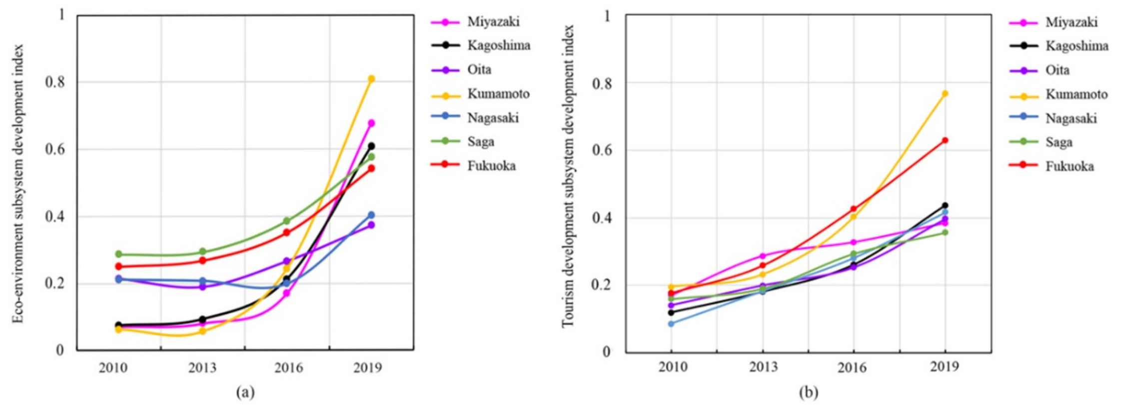

Figure 4. Development of subsystem indicators.

system, it can be seen that the slowest rate of ecological environment improvement in Oita Prefecture is mainly caused by S1 and S2 in the Pressure (F1) category, which means that a large amount of waste and waste gas was discharged from energy development during the research period.

Figure 4(b) shows the trend of tourism development indicators in the Kyushu region. Regarding the tourism index of the seven prefectures, only a small number of counties exhibit small growth fluctuations, with most showing a steady upward trend. Kumamoto and Fukuoka exhibit higher growth in the tourism index. Among them, the tourism index of Kumamoto increased from 0.19 to 0.77, the largest increase among the seven prefectures, which is due to the S17 indicator in the Supporting capability (F5) category and the S23, S24 indicators in the Evolutional capability (F7) category; that is, the high density and high tourism expenditure of the railway network and the improvement of tourism reception facilities or adequate. The main reason for the increase in the Fukuoka tourism index from 0.17 to 0.63 is S24 in F5 and S19 in F3; that is, tourism reception facilities are relatively sufficient, and there are many scenic spots. The tourism development indexes of the remaining five counties exhibit relatively lower growth rates, which points to insufficient momentum in tourism development. The annual average tourism system index is between 0.35 and 0.45, which is consistent with the reality of tourism in each prefecture.

4.2. Comprehensive development level of the environmental tourism system

As can be seen in figure 5, the combined level of ecological environment and tourism development continues to improve in each prefecture in the Kyushu region. The seven prefectures are divided into three main development ladders. The first ladder is Kumamoto, which has the highest and fastest development index, which grew from 0.129 in 2010 to over 0.686 in 2019, with a growth rate greater than 0.404 from

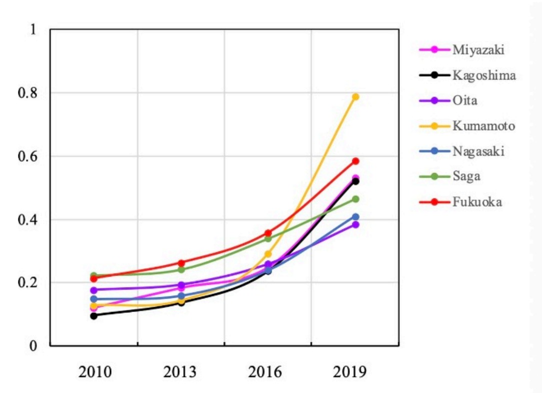

Figure 5. Comprehensive development index of ecological tourism (ET) system.

2016 to 2019. This is related to Kumamoto's significantly higher ecological environment and tourism development index than other prefectures. Miyazaki and Kagoshima are essentially at the same level, classified as in the second order, growing from around 0.1 in 2010 to around 0.5 in 2019. Although both prefectures have a better ecological environment, tourism development is seriously lagging, which led to a gap in their level of development compared to Kumamoto. The remaining four prefectures are on the final rung of the ladder, with a development index of around 0.4 by 2019. Of these, Oita has the lowest development index at 0.38. This is because both the ecological environmental system and the tourism development system in Oita are significantly less developed compared to the other prefectures.

4.3. Development characteristics of coupling coordination degree

To analyze the differences in the coupling coordination relationship (see table 2) between the ecological environment and tourism system in Kyushu in 2010, 2013, 2016 and 2019, this study made use of GIS software. These differences are temporally and spatially represented in figure 6, which clearly

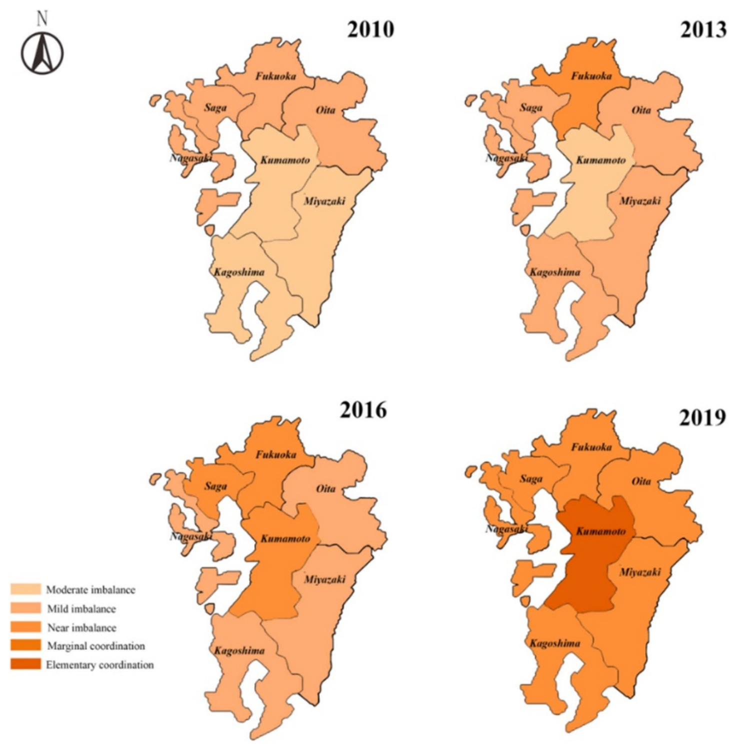

Figure 6. Spatial evolution characteristics of coupling coordination degree.

reflects the development of the coupling coordination degree of each prefecture.

From the perspective of spatial distribution, the seven prefectures can be divided into three grades based on the data related to the change in the coupling coordination degree analyzed by the membership function. (a) The first level includes Kumamoto, which grew rapidly from moderately imbalanced coordination to elementary coordination between 2010 and 2019. Although exhibiting the lowest degree of coupling coordination in 2010, as Kumamoto's ecological environment and tourism development indices were both high, the degree of coupling coordination rapidly increased to primary coordination in 2019. (b) The second level includes Kagoshima, which maintained steady growth in the degree of coupling coordination from 2010 to 2016, and picked up from 2016 to 2019 from mild imbalanced growth to marginal coordination. (c) The third level comprises Miyazaki, Oita, Nagasaki, Saga and Fukuoka, all of which exhibited low indicators for the ecological environment system and tourism development system. Differing from the other four prefectures, while Fukuoka's system index is not high and its tourism development index is much higher than the ecological environmental index, it still resulted in a low level of coordinated development.

For the region overall, an upward trend in the coupling coordination of ecological environment and tourism development systems was exhibited, resulting in evolution from moderate imbalance to elementary coordination over time. Figure 7 shows the wave-like evolution curve of the degree of coupling coordination. During the study period, the proportion of prefectures with moderate imbalance gradually dropped (42.86%→14.29%), the proportion of prefectures with mild imbalance rose and then dropped (57.14%→71.43%→57.14%), the proportion of prefectures with near imbalance rose (14.29%→42.86%), while the proportions of prefectures with marginal coordination and elementary coordination were 85.71% and 14.29% in 2019, respectively. The figure also shows a continual movement of the peak of the wave-like evolution curve of the coupling coordination degree to the right, which represents the gradual evolution of the degree of coupling coordination moving in a favorable direction, and that development of the

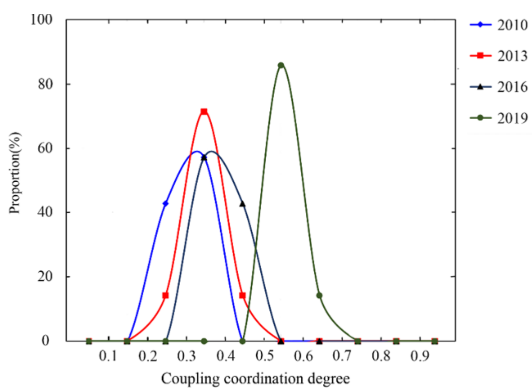

Figure 7. Evolution curve of coupling coordination degree.

ecological environment and tourism system proceeded continuously.

In summary, the coupling coordination level of the seven counties in the Kyushu region increased steadily from 2010 to 2019, showing a favorable development trend. However, regional deviations exist in terms of the coordinated development of the ecological environment system and the tourism development system, which has partly hindered protection of the ecological environment and tourism development. The reasons for this unbalanced development in the seven prefectures not only reside in qualitative differences in the ecological environment and the endowment of tourism resources, but also differences in management policies. Further, although the Shinkansen has contributed to an overall increase in the number of visitors to the Kyushu region year on year, the current tourism development model is uniform throughout the Kyushu region, which has similar product types, and lacks in-depth development of unique resources such as natural and cultural landscapes. This has resulted in fewer overnight visitors to the Kyushu area. Regarding Kumamoto, although its environmental index is not particularly high in relation to the Kyushu area, this prefecture in effect created its own brand through the use of an intellectual property (IP)-based image as a unique local mascot. Further, the prefectural government has continuously developed Kumamoto's economy by building a series of 'Kumamoto Bear'-branded entities such as the Kumamoto train station, offices and homestays. In addition, Kumamoto filed for the IP copyright of the Kumamoto Bear and continued to promote it while gradually building on the brand of Kumamoto Prefecture as a city. Such efforts to develop tourism placed this prefecture at the forefront of the Kyushu region, as well as Japan, in terms of the extent of tourism development.

4.4. Characteristics in the evolution of degree of coupling coordination

Based on the degree of synchrony between the respective development levels of the ecological environment system and the tourism development system, the coupling coordination degree categories can be divided into three types: (a) tourism lag type, in which the ecological environment development index is greater than the tourism development index; (b) synchronous type, in which the ecological environment index is approximately equal to the tourism development index; (c) ecological environment lag type, in which the ecological environment index is greater than the tourism development index.

As can be seen in figure 8, the level of ecological development and the level of tourism development in Oita Prefecture began to largely synchronize in 2013. Miyazaki and Kagoshima prefectures changed from exhibiting ecological lag to tourism industry lag toward the end of this study. In the early stages of tourism development in Kumamoto Prefecture, ecological environment lagged behind tourism development; in the middle stages, tourism development began to lag behind ecological environment; and at the end of development, the two systems were synchronized. Development of the four prefectures of Oita, Miyazaki, Kagoshima and Kumamoto illustrates the extent to which tourism development has improved the ecological environment in the region. Saga's tourism development lagged ecological development during the study period, indicating that the quality of tourism development in this prefecture needs to be improved. Fukuoka changed from a lagging tourism stage to a synchronous stage and then to a lagging ecological environment stage during the study period, which implies that the development of tourism in Fukuoka affects the quality of the ecological environment to some extent.

5. Recommendations

In response to the findings of this study, this paper proposes the following policy recommendations:

(a) Acknowledging the likelihood of prefectures in the ecologically lagging development stage aiming to pursue rapid development of tourism while failing to account for pressures on the ecological environment exceeding the environment's carrying capacity, future development should focus on the following points:
   1. The need for the government to strengthen tourism infrastructures, such as transport and public infrastructures.
   2. The need for the government to focus on developing regional ecotourism, focusing on the fragility of island ecosystems and the sustainability of resources in the Kyushu region.
   3. The need for the government to scientifically formulate tourism-related policies and plan tourism-related investments.

(b) For counties in the tourism development lag-type stage owing to the relatively low rate of tourism economy development and facing challenges in expanding the tourism industry scale, future development should focus on the following points:
   1. The need for the government to develop a variety of tourism products and create regional tourism brands based on local conditions. Although the Kyushu region is rich in hot spring resources, the functional positioning of tourism should not be limited to the hot spring experience but should make full use of unique regional resources and aspects of history to provide different kinds of tourism projects and thus enhance the quality of tourism available.

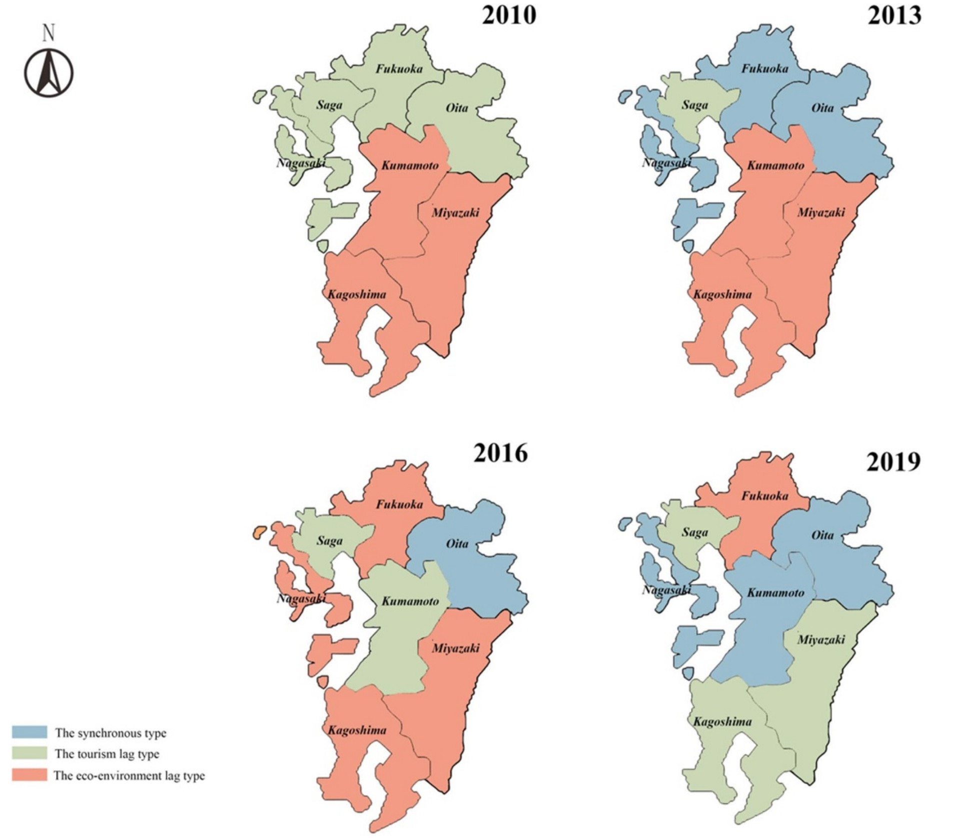

Figure 8. Characteristics in the evolution of degree of coupling coordination.

For example, resort tourism products, such as diving, fishing and luxury cruises, could be developed.

2. Prefectures in the Kyushu region have low numbers of overnight visitors; thus, each prefecture should determine the main tourism functions and themes it offers based on the specifics of its resource advantages. This could be achieved, for example, by digging deep into the essence of regional cultures to create a wealth of festivals and events to attract tourists, and bringing in well-known designers to create landmarks, cultural exhibitions and art festivals in conjunction with the characteristics of local resources.

6. Conclusions

The main results of this study are as follows:

(a) The ecological environment and tourism development in the Kyushu region are showing a trend of gradual coordination. However, there is a deviation between the regional coordinated development of the ecological environment system and the tourism development system.

(b) The degree of coupling and coordination between the ecological environment and tourism development system in Kyushu has changed from moderate coordination to marginal coordination, and the spatial pattern has changed from high in the north to low in the south to high in the middle and low in the surrounding area.

(c) The development of tourism in the four prefectures of Oita, Miyazaki, Kagoshima and Kumamoto has largely improved the ecological environment of the region. The development of tourism in Fukuoka Prefecture has affected the quality of the ecological environment to a certain extent.

(d) The Okinawa region was excluded from the spatial assessment of this study due to a lack of data, which may have affected the integrity of comparative development patterns in the regional coupling of the two systems. However, as one of the first studies to examine the coupling of ecological environment and tourism development in developed countries, the authors anticipate that future research will need to expand this increasingly important subject area.

Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

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