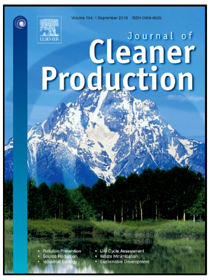

Ecological Security Evaluations of the Tourism Industry in Ecological Conservation Development Areas: A case study of Beijing's ECDA

Chengcai Tang, Xinfang Wu, Qianqian Zheng, Ning Lyu

PII: S0959-6526(18)31888-2

DOI: 10.1016/j.jclepro.2018.06.232

Reference: JCLP 13378

To appear in: *Journal of Cleaner Production*

Received Date: 29 November 2017

Accepted Date: 21 June 2018

Please cite this article as: Chengcai Tang, Xinfang Wu, Qianqian Zheng, Ning Lyu, Ecological Security Evaluations of the Tourism Industry in Ecological Conservation Development Areas: A case study of Beijing's ECDA, *Journal of Cleaner Production* (2018), doi: 10.1016/j.jclepro.2018.06.232

Ecological Security Evaluations of the Tourism Industry in Ecological Conservation Development Areas: A case study of Beijing's ECDA

Chengcai TANG, Xinfang WU, Qianqian ZHENG, Ning LYU

(School of Tourism Management, Beijing International Studies University, Beijing 100024, China)

*Corresponding author. Chengcai TANG, Ph.D, Associate Professor, Assistant Dean School of Tourism Management, Beijing International Studies University.

Address: No.1 Dingfuzhuang Nanli, Chaoyang District, Beijing, China, 100024.

E-mail: tcc5808@163.com; (86)13716975481

Acknowledgements

We thank the support provided by the National Natural Science Foundation of China (No. 41301161), the Beijing Social Science Fund (13JDZHC007), and the Project of Top-notch Young Higher Level Teaching Team Building Support Plan in Beijing Municipal Universities in 2017 (CIT&TCD201704067).

We also thank Donghui Ding (Master Degree Candidate of School of software engineering, South China University of Technology) for valuable suggestions, and Jingxian Li, Ruiqi Han, Yifan Wu and Man Liu (Undergraduates of School of Tourism Management, Beijing International Studies University) for the collection of the data used in this paper. The usual disclaimer applies.

Ecological Security Evaluations of the Tourism Industry in Ecological Conservation Development Areas: A case study of Beijing's ECDA

Highlights

- This study proposes a methodology for evaluating the ecological security of the tourism industry in an Ecological Conservation Development Area (ECDA).
- A case study from China is used to demonstrate the methodology.
- The paper examines the factors influencing the ecological security of the tourism industry in Beijing's ECDA.
- The findings contribute to the building of a theoretical framework for evaluating ecological security and provide practical references to support the sustainable development of the tourism industry in ECDAs.

Abstract: This study proposes a methodology for evaluating the ecological security of the tourism industry (ESTI) in Ecological Conservation Development Areas (ECDAs). Use of this methodology allows researchers to assess the level of sustainable development at tourist destinations. The Beijing ECDA in China was chosen as the study area. The research findings show that the composite index of ESTI for Beijing's ECDA improved rapidly during the years 2005-2014, and that there is great potential for further improvements in the future. The grades of ESTI in many sub-regions improved from Ⅱ or Ⅲ to Ⅳ or Ⅴ, and fluctuations in the level of ESTI sharply increased. Additionally, a gray relational grade model was used to calculate the gray correlation degree of the factors affecting ESTI in Beijing's ECDA. The main factors affecting ESTI in the Beijing ECDA were the response and factors related to government decisions and actions. A number of environmental indicators and indicators that gauge the development of the tourism economy have had an important impact on ESTI in the Beijing ECDA. This study explores new perspectives in the hope of developing a better understanding of the relationship between the sustainable development of the tourism industry and the ecological security of ECDAs. Such an understanding could enrich theories of tourism ecology and support the green development of the tourism industry. The findings of this study can also provide policymakers with ideas that can help in the formulation of effective policies to promote ESTI in ECDAs.

Keywords: ecological security evaluation; tourism industry; ecological conservation development area; green development; Beijing

1 Introduction

Rapid urbanization has brought with it numerous ecological and environmental changes that seriously threaten ecological security (Gibbs D and Longhurst J, 1995; Su Y et al., 2016). How to balance the relationship between urban construction and the maintenance of ecological security in the overall urbanization process is an issue of great concern (Xie H et al., 2015; Zhao Y et al., 2006). Ecological Conservation Development Areas (ECDAs) play a very important ecological support role in the sustainable development of the cities they are near (Jogo W and Hassan R, 2010; Zhang F et al., 2017). In the case of Beijing city and the rural districts that make up the Beijing ECDA, environmental protection policies have been implemented that prohibit or limit the operations of industrial facilities and activities like coal mining that degrade the environment and produce unacceptable amounts of pollution. Thus, government decision makers and many scholars are paying considerable attention to how regions like the Beijing ECDA choose appropriate industries that support sustainable development and provide alternative livelihoods for local residents who have lost work as a result of policy changes (Jogo W and Hassan R, 2010; Liu C et al., 2014). Many studies indicate that the development of tourism can to some extent balance the conflicting needs for social and economic development and for environmental protection in these regions (Tang C et al., 2009). Therefore, the tourism industry has become an important source of alternative livelihoods in ECDAs (He D et al., 2010; Mao X et al., 2016; Zhang J et al., 2016). However, if damage from environmental pollution caused by development of the tourism industry exceeds an acceptable ecological security threshold for the regional environment, it will threaten ecological service functions and the sustainable development of the ECDA in the region (Liu X et al., 2009).

Ecological security has emerged in recent years as a new conceptual paradigm. Many scholars have carried out ecological security assessments on the national (Liu Y et al., 2017) and regional levels (Chu X et al., 2017; Han B et al., 2015; Zhao Y et al., 2006), and for cities (Gong J et al., 2009; Huang H et al., 2017), wetlands (Jogo W and Hassan R, 2010), nature protected areas (Gong M et al., 2017) and tourist destinations (Cao X et al., 2006; Liu X et al., 2009). The concept of ecological security has been integrated into earlier research on ecotourism and sustainable tourism (Hunter C and Shaw J, 2007; Simon et al., 2004; Sun and Wang, 2000; Yu, 1999), and the ecological security of tourism destinations has been the subject of widespread public concern (Liu X et al., 2009; Ross and Wall, 1999; Zhou B et al., 2015). Previous studies have established evaluation models and indicator systems that allow for the study of the ecological security of the tourism industry (ESTI) from different perspectives (Liu X et al., 2009). These all take into consideration various factors related to the ecological environment, society, economy and tourism development and are used indices to evaluate ESTI.

Scholars have examined the ESTI of scenic spots (Dong X, 2004), tourism cities (Cao X, 2006) and provinces (Zhou B et al., 2015). However, there remains an evident lack of understanding of the relationship between the sustainable development of the tourism industry and the ecological security of ECDAs. This paper is an attempt to fill this gap.

Beijing Municipality is a provincial-level administrative entity in China consisting of a core urban area and several rural districts located mostly to the north and west of the urban core. Beijing's ECDA accounts for approximately 68.9% of the entire area of Beijing, and includes Yanqing, Pinggu, Huairou, Miyun, Mentougou districts, and parts of Changping and Fangshan districts. It is not only an important ecological barrier and conservation area for water sources in the capital of China, but also a support area to guarantee the sustainable development of the Beijing metropolitan area. Many scholars have searched for ways to resolve the conflicts between the needs for social and economic development and for ecological environmental protection in Beijing's ECDA. There is also an urgent need to identify industries that can provide alternative livelihoods (SGBMCCDL, 2007; He D et al., 2010; Tang C et al., 2014). In recent years, tourism has become a leading industry in Beijing's ECDA (Sun C et al., 2016) and a variety of tourism products like leisure agriculture (Zhang J et al., 2016), ecological and folk tourism (Mao X et al., 2016) and rural tourism (He D et al., 2010) are now available. However, with the rapid development of the tourism industry in Beijing's ECDA, ecological threats and environment pollution have become problems (He D et al., 2010; Tang C et al., 2014; Tang C et al., 2017). Some scholars have begun using ESTI to undertake quantitative evaluations of the environmental capacity of tourism in Yanqing (Gao J et al., 2015) and the environmental quality of tourism in Huairou (Liu T and Zhang B, 2009), both of which are rural locales in Beijing's ECDA. However, because the scale of the research is limited to single functional sub-regions, or the research perspective is limited to the environmental capacity of tourism, these studies have limitations. In an effort to address such limitations, this paper uses a case study of Beijing's ECDA to examine the factors that influence ESTI and, based on this examination, proposes a general methodology for evaluating ESTI in ECDAs. This methodology is intended to serve as a tool to assess the level of sustainable development at tourist destinations.

Thus, this study explores new perspectives and endeavors to develop a better understanding of the relationship between the sustainable development of the tourism industry and the ecological security of ECDAs. This innovative approach to analyze the environmental impact of tourism activities from the perspective of ESTI can contribute to the development of a theory of ESTI for ECDAs and enrich theories of tourism ecology. It is hoped that the findings of this study will provide policymakers with ideas for formulating effective policies to promote ESTI in ECDAs.

2 Literature review

2.1 Ecological security of the tourism industry

The concept of ecological security has been applied in many research fields (Liu Y et al., 2017; Yang Q et al., 2018). The concept of tourism ecological security has grown out of the concept of ecological security (Ezeonu I and Ezeonu F, 2000; Zhou B et al., 2015). The ESTI provides an objective foundation to assess the sustainable development of tourism destinations (Tang C et al., 2013). To date, a limited number of ESTI studies have been undertaken from several disciplinary perspectives: geography (Tang C et al., 2013), environmental science (Jurado E N et al., 2012), tourism science (Xiong H et al., 2003), ecology (Zhang J et al., 2008), and energy science (Tang C et al., 2015, 2017). In terms of research content, scholars have studied the ideological origins of ESTI (Lu J, 2007), the concepts and connotations of ESTI (Zou J, 2008), ESTI measurements and evaluations (Li X, 2017), ESTI forecasts (Zhou B et al., 2016), dynamic simulations of ESTI (Wu C et al., 2013), early warning methods for ESTI (Xu M et al., 2017) and developmental countermeasures (Zhou D., 2011). Some scholars have used different spatial scales, studying regions (Yin J and Zheng X, 2017; Zhang P and Qiu P, 2014), provinces (Cheng G and Yue X, 2011), cities (Cao X, 2006; Li Y et al., 2013; Liu H, 2013), or scenic spots (Liu T et al., 2009; Zhang J et al., 2008) to evaluate the ESTI. Some scholars have evaluated the ESTI of different types of tourist destinations, such as islands (Xiao J et al., 2011; Zhou B et al., 2015), grasslands (Lu J., 2008), scenic areas (Dong X, 2003; Lin D, 2012), wetlands (Li S et al., 2012), plateaus (Zhao Y et al., 2006), mountains (Li R et al., 2010), and forests (Zheng Y et al., 2015).

A number of methodologies are used to evaluate the ESTI: environmental impact assessments of tourism (Green H and Hunter C, 1992), tourism carrying capacity (O'Reilly A, 1986), a limits-of-acceptable-change system of tourism development (McCool S, 1994), an improved TOPSIS method (Zhou B et al., 2015), the Pressure-State-Response (P-S-R) framework (Li R et al., 2010), the ecological footprint (Gössling S et al., 2002; Hunter C, 2002; Hunter C and Shaw J, 2007; Martín-Cejas R and Sánchez P, 2010; Xiao J et al., 2011), and complex system theory (Yang C, 2009). Scholars often establish a quantitative models by building index system for evaluations of the ecological security of tourism industry, the P-S-R model (Zhang P and Qiu P, 2014; Li R et al., 2010; Yang Z and Zhang Z, 2014) and the driving force pressure state impact response (DPSIR) model (Li Y, 2012) are examples. Other scholars have used remote sensing analysis (Kurniawan et al., 2018) or gray relational analysis (Zhou B et al., 2015) to analyze the factors influencing ESTI.

A summary of ESTI research results, organized in terms of their methods and the indicators used, are presented in Table 1. Existing studies have developed effective models that establish indicator systems for evaluating ESTI using both qualitative and quantitative methods (Tang C et al., 2013; Zhang J et al., 2008). The choice of methodology used to study ecological security evaluations of the tourism industry depends on the research objectives. It is thus necessary for researchers to establish an indicator system for the ESTI that is appropriate to their research area. Many scholars are concerned with ecological security evaluations of the tourism industry that focus on a particular point in time (Cao X, 2006; Zhang P and Qiu P, 2014). These studies ignore dynamic analyses (Su M and Fath B, 2012), and do not offer in-depth analysis of the reasons ecological security levels have evolved along particular paths (Hong W et al., 2016). The evolution of temporal spatial patterns and how these influence the ESTI in different types of tourist destinations should be the focus of future research. P-S-R and P-S-R-EES, which have proven useful to this study, provide a socioeconomic framework to track the causality process of environmental degradation (Wei Y et al., 2015).

(Insert Table 1)

Table 1 Summary of relevant ESTI research results

2.2 ECDAs and the development of the tourism industry

The concept of ECDA was first developed in Beijing in 2012. It was part of the city’s functional area planning process and seen as a way to safeguard the city's ecological security. Subsequently, other provinces and cities began including the establishment of ECDAs as part of their functional area planning processes; the Chongqing northeast

ECDA, the Kunming ECDA, the Hebei ECDA are examples. Serving as primary water resource conservation areas and ecological barriers for cities, ECDAs provide ecosystem services to support the sustainable development of urban areas (Jin H and Liu S, 2016), including, among others, restoration of vegetation, water conservation, soil and water loss control, and sand control (Ma C et al., 2017).

Although similar to ecological protection areas, ECDAs have their own characteristics. First, an ECDA is focused on the key ecological functions of water conservation and soil maintenance (Jin H and Liu S, 2016), and water and forest ecosystems are crucial to the ECDA (Ma C et al., 2017). Second, the ECDA is defined as a restricted development area, due to its important ecological functions and vulnerable environment (Zhang L, 2009). The ECDA is purposed to host eco-friendly industries, not large-scale, high-intensity industrial facilities or large urban centers (He D et al., 2010). Third, the ECDA is subdivided by local authorities and territorial planning experts in accordance with the requirements of national-level main functional area planning (Ma C et al., 2017). An ECDA is composed of many administrative villages, a limited number of urban areas, and vital conservation zones like national-level natural reserves and forest parks.

Some scholars have conducted ecological security evaluations in regions with fragile, sensitive ecosystems, such as the Tibetan Plateau (Zhong X et al., 2010), the Loess Plateau (Li J et al., 2006), the Karst region (Liao C et al., 2004), river basins (Feng Y et al., 2014), and lake areas (Wang S et al., 2015). Other scholars have examined important ecological functions in certain regions, such as the ecological footprint of the Mediterranean region (Baabou W et al, 2017) or of Rawalpindi (Rashid A, et al. 2017), the urban ecological security in Shenzhen (Hong W et al., 2017), and the ecological security of land in the Chongqing ECDA (Wang X., et al., 2014).

The development of the tourism industry can to some extent coordinate the conflicting needs for social and economic development and environmental protection in ECDAs. The tourism industry has also become an important source of alternative livelihoods in ECDAs (He D et al., 2010; Mao X et al., 2016; Tang C et al., 2009; Tang C et al., 2012; Zhang J et al., 2016). However, the excessive exploitation of the natural environment by the tourism industry can seriously endanger the ecological security of ECDAs. The tourism industry in the Three Gorges Reservoir area, for example, has developed rapidly in recent years, and ecological security issues are emerging as a result (Wang H et al., 2012). The development of tourism resources in the Ordos region has brought with it ecological security hazards as well. While problems are often not visible during the early stages of tourism industry development, crises become more likely during the middle stages (Jia T and Feng Y, 2012). A number of scholars have focused on ESTI in the Beijing ECDA. These scholars have engaged in research to measure the capacity of the environment of the Yanqing district to support tourism (Gao J et al., 2015), to examine the rural ecological tourism footprint in Liugou village of the Miyun district (Li Y and Jin L, 2014), to evaluate the development level of low-carbon rural tourism in Mentougou district (Luo H and He Z, 2015), and to assess the quality of the tourism environment in Huairou district (Liu T and Zhang B, 2009). To date a number of studies exploring tourism development and ecological security in ECDAs, both in Beijing and elsewhere, have produced useful results. However, there remains a lack of research offering overall system evaluations of ESTI. Given the importance of relationship between the development of the tourism industry and ecological security management in ECDAs, robust evaluations of the ecological security of the tourism industry are key to promoting the ecological conservation function of these regions and ensuring the sustainable development of the social economy.

3 Study area

The Beijing ECDA has an excellent ecological environment and rich natural resources. It acts as an ecological barrier and a protection area for Beijing's water sources (Wang X and Yuan H, 2009). The area is key to ensuring the sustainable development of China's capital and is an important component of efforts to construct a more livable city (Guo F, 2008). Beijing's ECDA includes the Yanqing, Pinggu, Huairou, Miyun, and Mentougou districts and the mountainous parts of Changping and Fangshan districts, and covers a total land area of 11.3 thousand km^2 accounting for approximately 68.9% of Beijing's total area. Each of the districts is an administrative sub-area in the Beijing ECDA (Figure 1).

(Insert Figure 1 here)

Figure 1. Beijing's ECDA sub-areas

Beijing's ECDA has been selected as the study area for the following reasons: First, Beijing's ECDA is an important provider of the ecological service functions that support urban sustainable development. Second, because millions of people live in the area that comprises the Beijing ECDA, there exist a number of the conflicts that typically make it difficult to balance the need for economic and social development with the need for ecological protection. Third, the rapid development of the tourism industry in Beijing's ECDA has resulted in pressure and threat to the ecology of the area. Beijing's efforts to deal with the relationship between the sustainable development of the tourism industry and the ecological security of the Beijing ECDA are typical of such efforts.

4 Methodology

4.1 Framework for evaluating ESTI

The methodology used by this study for evaluating ESTI in ECDAs is composed of five parts: the indicator system of ESTI in ECDAs, improved TOPSIS method, a hierarchical dynamic model of ESTI, Markov chains, and the gray relational grade model. The study's evaluation framework for ESTI in ECDAs is shown in Figure 2.

(Insert Figure 2 here)

Figure 2. The framework for evaluating ESTI in ECDAs

4.2 Indicator system for evaluating ESTI in ECDAs

The Pressure-State-Response (P-S-R) framework is commonly used for ecosystem health assessments that are part of environmental quality assessments (Rapport DJ and Friend AM, 1979; Zhou B et al., 2015). Some scholars have combined the P-S-R framework with an "economy-environment-society" (EES) model to construct an ESTI indicator system based on a P-S-R-EES framework. ESS not only enriches the P-S-R framework structure, but combining the P-S-R and ESS models also achieves better results (Zhou B et al., 2015; Li X et al., 2017). Therefore, this paper adopts the P-S-R-EES framework to evaluate ESTI.

This paper used Delphi method to establish an indicator system for ESTI in ECDAs. First, we selected a panel of ten experts in the fields of urban studies, ecology, geography, tourism and sustainable development. Second, we designed questionnaires for the experts based on items that are related to the research question. Third, we carried out two rounds of consultations with the experts and used their suggestions to modify the indicator system for ESTI in ECDAs. Based on previous research results (Ma C et al., 2017; Zhang L., 2009; Zhou B et al., 2015), and the results of our consultations with the expert panel, the indicator system for ESTI in ECDAs used by this study was constructed using the following factors: the economy, the ecological environment, and the society. First, indicators for economic development including the density of the tourism economy, the tourism revenue growth rate, the number of travel agencies, and the number of star-rated hotels, are important factors for measuring the ESTI in ECDAs. Second, indicators for the ecological environment are the most important factors for measuring the ESTI in ECDAs, and these indicators include the annual growth rate of ecological environment replenishment, the total amount of waste water discharge, the wastewater treatment rate, and per capita green area, etc. Third, social indicators for visitor density, urbanization rate, and the proportion of environmental protection expenditure to GDP are also important for measuring the ESTI in ECDAs. The references and attributes of the indicator system are shown in Table 2.

(Insert Table 2 here)

Table 2 Indicators for evaluating ESTI in ECDAs based on the P-S-R-EES framework

4.3 Improved TOPSIS method

The improved Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method is based on multi-objective decision analysis and used to define a measurement in the target space to determine the degree to which the target is near the positive ideal solution and away from the negative least ideal solution (Hwang C and Yoon K, 1981). Compared with the traditional TOPSIS method, the evaluation object and method for positive and negative solutions has been improved based on the use of mean square error method in improved TOPSIS. The improved approach places no strict limits on data distribution and the sample index (Wang L et al., 2015). The method is not only for use with small data samples, but can also be used with multiple evaluation objects and multiple indexes. It can be used to compare horizontal multiindexes and make longitudinal analyses of different years (Xu M et al., 2017). Compared with methods like weighted sum and fuzzy comprehensive evaluation, improved TOPSIS has authentic, intuitive and reliable advantages, and has been used successfully by many scholars (Lu C et al., 2011; Xu M et al., 2012; Zhou B et al., 2015). The evolution of ESTI in each ECDA has its own particular characteristics. For example, the optimal level of ESTI varies at different time periods. Therefore, this paper uses the improved TOPSIS method based on mean square error method to evaluate the ESTI in ECDAs. The specific calculation steps are as follows:

First, the evaluation indicator weight w_i is calculated by the mean square error method. The weight of the evaluation indicator w_i and the standard decision matrix r_{ij} are multiplied to obtain the weighted standardized decision matrix v_{ij} (Zhou B et al., 2015).

$$v_{ij} = w_i \times r_{ij} \qquad （1）$$

Where i is the number of evaluation indicators and j is the number of evaluation objects.

Second, the ideal positive and negative solutions are determined, and the distances between each evaluation object and the positive and negative solutions (D_j^+ andD_j^-) are calculated. Finally, the relative connection degree (C_j) of each evaluation object and each solution is calculated (Zhou B et al., 2015; Xu M et al., 2012).

$$C_j = \frac{D_j^-}{D_j^- + D_j^+} \qquad （2）$$

Where C_j is the indicator value of ESTI, with a value between 0 and 1; the larger the value, the better the ESTI in an ECDA.

4.4 Hierarchical dynamic model of ESTI

Based on the indicator value, the ESTI in an ECDA can be divided into seven grades (Table 3).

(Insert Table 3 here)

Table 3 The grades of ESTI in ECDAs

Based on the ecological security grade classifications, a dynamic model is used to calculate the change rate of the ecological security grade (Zhou B et al., 2015). This can be understood to indicate the evolutionary trend of ESTI in an ECDA in a given year.

$$V = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \qquad （3）$$

Where V is the dynamic degree of the grade of ESTI in two periods, U_a and U_b are the respective values of the grade of ESTI at the beginning and the end of the study, and T is the research period.

4.5 Markov chains

Markov chains are discrete Markov processes for both time and state (Pu Y et al., 2005). Ecological security evolves both temporally and spatially, and this characteristic is consistent with the nature of the Markov process. Markov chain theory is used to construct a model describing the spatial and temporal evolution of ecological security grades (Zhou B et al., 2015). The model can be used to analyze the probability of the ecological security grade evolving temporally, and analyze spatial correlations and changes to the ecological security grade (Xue L and Ren Z, 2011). Some scholars have applied Markov chains to analyze the spatial-temporal evolution of regional ecological security (Wang G et al., 2013; Zhou B et al., 2015). This paper also uses Markov chains to explore the spatial-temporal evolution characteristics of ESTI grades in the Beijing

ECDA. Based on the characteristics of Markov chains, the probability distribution of the ESTI grade in *t* year is expressed as a state probability vector P_t of $1\times k$, denoted as $P_t=[P_{1,t}, P_{2,t}, \ldots, P_{k,t}]$. ESTI grades in different years can be expressed with a Markov transition probability matrix $A=(a_{ij})_{m\times n}$, as shown in the following (Zhou B et al., 2015; Wang L et al., 2010):

$$a_{ij}=\frac{b_{ij}}{b_i} \qquad (4)$$

Where a_{ij} indicates that the probability of the type *i* of ESTI in *t* year changing to the type *j* of ESTI in the next year. b_{ij} indicates the sum of the number of areas, where type *i* of ESTI in t year changed to type *j* in the t+1 year. b_i is sum of the number of areas belonging to type *i* in all years. The transition probability of the grades of ESTI and their relationships with the surrounding neighborhood are analyzed by comparing the values of Markov matrix elements.

4.6 Gray relational grade model

Compared with structural equation modeling (Zheng Y et al., 2015), gray relational grade models are simpler and offer a more reliable way to analyze the factors influencing ecological security (Zhang J et al., 2014). The ecological environments of ECDAs are fragile and subject to numerous factors whose influence is unpredictable, such as natural disasters or economic development that results in high levels of pollution. The element of uncertainty makes ECDAs gray systems (Wu X and Wu Y, 2014). Therefore, this paper uses a gray relational grade model to analyze the interrelationships of the ESTI system in ECDAs. The calculation steps are as follows:

First, equation (5) calculates the gray slope correlation coefficient (Zhou B et al., 2015), where $y(k), k=1, \ldots, m$ is the generating function series, $x_i(k), i=1, \ldots, n$ is the sub-function sequence, ξ is the correlation coefficient of *y (k)* and *xi (k)* in *k* year. σ_{x_i} and σ_y are, respectively, the standard deviations of generating function *y* and the sub-function sequence x_i, $\Delta x_i(k) = x_i(k+1) - x_i(k)$, $\Delta y(k) = y(k+1) - y(k)$. In this study, the generating function *y(k)* is the comprehensive evaluation value of the ESTI, and the sub-function $x_i(k)$ is the value of the standardization of evaluation indicator *i*.

$$\xi = \frac{1}{1 + \left| \frac{\Delta x_i(k)}{\sigma_{x_i}} - \frac{\Delta y(k)}{\sigma_y} \right|} \qquad (5)$$

Second, equation (6) calculates the gray relational grade (Zhou B. et al., 2015). In the formula, *r* represents the relational grade between the sequences $x_i(k)$ and *y(k)*, and the order of its size indicates the influence degree of the sub-function on the generating function. A larger *r* value indicates that this evaluation indicator has a greater degree of influence on the grade of ESTI in the ECDA.

$$r = \frac{1}{n-1}\sum_{k=1}^{n}\xi(k) \qquad (6)$$

4.7 Data Sources

The data for the indicator system used to evaluate ESTI in the Beijing ECDA were collected from three sources: (1) editions of the *Beijing Statistical Yearbook* for the years 2005-2015, various editions of the *Statistics Bulletin of National Economic and Social Development of Beijing* for the years 2005-2015, and bulletins on the environmental status of Beijing during the years 2005-2015; (2) *The Beijing ECDA Statistical Yearbook* for the years 2005-2015, *The Beijing ECDA Statistical Bulletin of National Economic and Social Development* during the years 2005-2015, and Bulletins on the environmental status of Beijing's ECDA during the years 2005-2015; (3) statistical data for the tourism industry in the Beijing ECDA during the years 2005-

2015. The average and range methods were used to standardize the original data in this paper.

5 Results and analysis

5.1 The temporal characteristics of ESTI

5.1.1 Security indexes of the subsystems

The improved TOPSIS method was used to calculate the security indexes of the pressure subsystem, state subsystem and response subsystem for the ESTI in Beijing's ECDA from 2005 to 2014 (Table 4).

(Insert Table 4 here)

Table 4 Subsystem security indexes for ESTI in Beijing's ECDA from 2005 to 2014

(1) Pressure subsystem. The pressure subsystem index of ESTI in Beijing's ECDA rose from 0.374 to 0.522 from 2005 to 2014. The state of ecological security evolved along the path "risk – sensitive – critical security." The pressure subsystem of ESTI was in danger throughout the years 2005 to 2007. During this period, the number of tourist arrivals increased rapidly with annual average growth rates of 12.47% to 13.62%. Total waste water discharge increased from 480.26 million tons to 509.61 million tons from 2005 to 2007. The annual average concentration of SO_2 surpassed 37.57 mcg/m^3, much higher than it had been in previous years. Less than 70% of the days in each of these years attained the Grade II standard for urban air quality, and this percentage was lower than in other years. The security level of the pressure subsystem improved rapidly in 2008, mainly due to a sharp decrease in the amount of waste water discharge and garbage, and improved air quality. These improvements may have been related to the preparations for the Beijing 2008 Summer Olympics. The Beijing government introduced a series of environmental policies and measures to improve the ecological environment, and these have positively affected the level of ESTI in the pressure subsystem for Beijing's ECDA in recent years. The pressure subsystem of ESTI during 2010-2015 stabilized at a critical security level.

(2) State subsystem. The state subsystem index of ESTI in the Beijing ECDA improved from 2005 to 2014. This subsystem evolved along the path "deterioration - risk - sensitive - critical security - relative security" and showed a trend of year on year improvement. The security index of the state subsystem increased from 0.224 to 0.764 from 2005 to 2014, with an annual average increase of 14.61%. This was due to a gradual improvement of the internal factors of the ESTI state subsystem. The tourism industry in the Beijing ECDA grew rapidly during the years 2005 to 2014 and a range of tourism services were developed during this period (e.g. rural folk tourism and ecological leisure agriculture). Tourism revenue increased from RMB 6.03 billion to RMB 33.31 billion from 2005 to 2014, with average year on year growth of 20.9%. The number of folklore tourism operators and sightseeing gardens increased from 9356 and 747 in 2005 to 13,145 and 1007, respectively, in 2014. It can be seen that the steady improvement of the state subsystem security index benefited from the rapid development of the tourism industry, which has gradually become an important alternative livelihood industry in Beijing's ECDA. In addition, local governments in the Beijing ECDA are paying close attention to the development of beautiful scenery and "Green Beijing", both of which help to improve the level of ESTI. Green garden areas and per capita green space in Beijing's ECDA have increased, respectively, from 182.84 km^2 and 52.5m^2 in 2005 to 351.17 km^2 and 68.8m^2 in 2014. These increases form a good basis for ESTI. However, the state subsystem index of ESTI has increased slowly. The average annual growth rate of green garden area was 7.5% and that of per capita green space only 3.04% from 2005 to 2014.

(3) Response subsystem. The response subsystem index of ESTI in the Beijing ECDA increased from 0.488 in 2005 to 0.457 in 2014; the minimum index value was 0.417 in 2013 and the maximum was 0.538 in 2008. The response subsystem evolved along the path “sensitive - critical security - sensitive - critical security – sensitive.” Movement along the path was characterized by fluctuations, showing first an increase, then a sudden drop, then a gradual increase and finally a decline. From 2005 to 2014, the security grade of the response subsystem moved back and forth between “sensitive” and “critical security”, but was mostly in the “sensitive” grade. This indicates that the security level of the response subsystem was not stable, and was easily affected by the external environment. There is still much room to improve the security level of the response subsystem in this area. In recent years, the Beijing government has worked steadily to coordinate ecological conservation and economic and social development, to cultivate environmentally friendly industries like tourism and leisure, and to develop ecological agriculture. The economic level of Beijing’s ECDA has improved as a result. The proportion of fiscal revenue as a part of GDP has risen from 19.67% to 39.41%, the proportion of service industry revenue as a part of GDP has remained at about 55%, and the proportion of tourism income as a part of GDP has increased from 11.8% to 22.83%. Economic growth of Beijing’s ECDA helps to ensure that funds for environmental protection work are available; the proportion of environmental investment as a part of GDP has remained at around 3% in the Beijing ECDA. However, the response subsystem of the Beijing ECDA still does not provide sufficient protection against threats to the environment. The waste water treatment rate in the Beijing’s ECDA was only about 50% in 2014, far below the 86.1% average value for Beijing as a whole. The rate of harmless disposal of household garbage in Beijing’s ECDA was about 70% and that for the comprehensive utilization of solid waste was only 66%; both of these rates are far below the average rates for Beijing as a whole (99.6% and 87.7%, respectively). It can be seen that environmental protection in the Beijing ECDA is relatively undeveloped, and this makes the grade of security for the ESTI response subsystem to be in a sensitive state. The relatively low rate of waste water treatment, harmless disposal of household garbage and comprehensive utilization of solid waste lower the ESTI in the Beijing ECDA.

5.1.2 Composite index of ESTI

The composite index of ESTI in Beijing's ECDA increased from 0.361 to 0.580 from 2005 to 2014, and the security status of the index rose from "risk" to "critical security" (Table 5). The composite index was at the "risk" grade in 2005 and 2006, but rose to the "sensitive" level in 2007 and remained there until 2009. This improved situation in Beijing's ECDA may have benefited from environmental protection projects undertaken to prepare Beijing for the 2008 Olympics. The composite index of ESTI was at the "critical security" grade from 2010 to 2014, a higher grade than in previous years. The Beijing government carried out a series of ecological environmental protection projects, such as the "Green Beijing" action plan (2010-2012), that were part of the Twelfth Five-Year Plan (2010-2015). Implementation of these projects improved the composite index of ESTI in the Beijing ECDA, but overall, there is still considerable room to improve. The grade of "critical security" suggests that conditions are complex and susceptible to the external environment. There can be further damage or improvements to the environment; the area is still far from reaching the extreme security grade.

(Insert Table 5 here)

Table 5 The composite index of ESTI in Beijing's ECDA from 2005 to 2014

5.2 Spatial characteristics of ESTI

5.2.1 Spatial changes to ESTI grades

The ESTI indexes of the seven sub-areas in the Beijing's ECDA were calculated using improved TOPSIS, based on the characteristics of time series changes to ESTI in the Beijing's ECDA for the years 2005, 2008, 2011 and 2014. Based on the ecological security grade classification presented in Table 3, a spatial distribution map was generated using ArcGIS 9.3 (Figure 3).

(Insert Figure 3 here)

Figure 3. Spatial variation of ESTI grades in Beijing's ECDA from 2005 to 2014

The ESTI grades of the seven Beijing's ECDA sub-areas from 2005 to 2010 ranged from the grade II "risk" to the grade IV "general security". All of the areas were at the risk grade in 2005, but in 2008 all of them had improved (moved higher) to the secure grade. The ESTI grades of Yanqing, Pinggu, Huairou, Mentougou and Changping districts increased from grade II to grade III. Of particular note, the grades of ESTI of Fangshan and Miyun districts jumped to grade IV. In 2011, the ESTI grades of Huairou and Miyun were still at grade III, while the other sub-areas were at grade IV. In 2014, the grades of ESTI in Miyun, Mentougou and Fangshan were at grade IV, while the remaining four sub-areas were at grade V. In summary, the number of sub-areas with ESTI grades of II and III lessened, and by 2014 all of the sub-areas were either grade IV or grade V. The improvement of ESTI grades in the sub-areas of Beijing's ECDA was due mainly to the following reasons: the Beijing government implemented a range of plans, policies, financial measures and ecological compensation efforts to promote protection of the ecological environment and support ecological civilization construction in the ECDA. Moreover, the government has encouraged development of a "green" tourism industry providing services such as ecological agriculture and rural tourism.

5.2.2 Spatial change rate of the ESTI grades

The spatial change rate of the ESTI grades in the Beijing ECDA was calculated using a hierarchical dynamic model for ecological security. It can be seen that the number of Beijing ECDA sub-areas with ESTI of grade II decreased by 33.33% during the years 2005-2008. During the years 2008-2011, the number of sub-areas with ESTI of grade IV increased by 50%, while the number of sub-areas with ESTI of grade III decreased by 20%. From 2011 to 2014, the number of sub-areas with ESTI of grade III decreased by 33.33%, and the number of sub-areas with ESTI of grade IV decreased by 20%. In sum, the level of ESTI grades in the Beijing's ECDA became higher from 2005 to 2014, while ESTI grade II dropped at a rate of 33.33%. The number of sub-areas with grade V ESTI increased from zero in 2005 to four in 2014. This indicates that over time the spatial change rate of ESTI grades in the Beijing's ECDA became faster and showed a trend of improvement.

5.2.3 Spatial transfer characteristics of the ESTI grades

The spatial transfer probability matrix for ESTI grades during the years 2005 to 2008, 2008 to 2011, and 2011 to 2014 was constructed using the Markov chain model (Table 6). The elements in the diagonal of the matrix indicate that the ESTI grade did not transfer, while the off-diagonal of the matrix represents the probability of transition. From 2005 to 2008, the probability of grade II transferring to grade III was 0.714 and to grade IV was 0.286. The probabilities of grade III and grade IV remained unchanged at 0.2 and 0.5, respectively, in the transfer probability matrix during the years 2008-2011. The probabilities of the grade II and grade III transferring to grade IV were 1 and

0.8, respectively, during the years 2008-2011. However, the probability of grade IV transferring to grade III was 0.5. This indicates that spatial transfer of ESTI grades in the Beijing ECDA had fluctuating characteristics during the years 2008 to 2011; the probability of changing to grade IV was high, but the direction of individual grade transfers was uncertain.

(Insert Table 6 here)

Table 6 Markov matrix of transfer probabilities for the ESTI grades of Beijing's ECDA from 2005 to 2014

From 2011 to 2014, the probability that grade III would jump to grade IV and then to grade V was 0.5. The probability that grade IV would remain unchanged was 0.4, and that it would transfer to grade V was 0.6. The probability of spatial transfers of ESTI grades was higher during this period. It is likely that the security level in one area was affected by the security level in neighboring areas, and this resulted in the grade in the local area moving higher. In general, the spatial transfer matrix for ESTI grades in the Beijing's ECDA for the years 2005 to 2014 showed ESTI grades gradually shifting higher, albeit with considerable fluctuations.

5.3 Important factors affecting ESTI

The gray correlation degree of the factors influencing ESTI in the Beijing ECDA was calculated and sequenced using a gray relational grade model (Table 7). The top 20% of the total number of evaluation indicators were selected as the main factors influencing ESTI in the Beijing ECDA. Table 7 shows the important factors affecting ESTI from 2005 to 2014: the annual concentration of SO_2, the annual growth rate of water replenishment in the ecological environment, total tourism revenue as a proportion of GDP, the green coverage rate, the number of star-rated hotels, the proportion of days each year with air quality at level two or better, the comprehensive utilization rate of solid waste, and the harmless treatment rate of household garbage. The gray correlation degrees of these factors are 0.655, 0.654, 0.614, 0.608, 0.607, 0.606, 0.605, and 0.601, respectively.

(Insert Table 7 here)

Table 7 Gray correlation degree between the ESTI and influencing factors from 2005 to 2014

In addition to its connection to local conditions, ESTI is also connected to a regional ecological environment. Key indicators for the ecological environment account for a large proportion of the factors influencing ESTI in Beijing's ECDA. First, air quality indicators include the annual average concentration of SO_2, and the proportion of days each year with air quality at level two or better. Recently, air quality has become an increasingly important factor affecting the development of the tourism industry in Beijing. Smog and haze affect the protection and development of tourism resources, and have the potential to impact the safety of the tourism industry. This could lead to diminished benefits to the economy, society and ecological environment from regional tourism (Tang C et al. 2016). This paper offers additional confirmation of the fact that the air quality index has a significant impact on the ESTI of the Beijing ECDA. It is also worth noting that the annual growth rate of water replenishment in the ecological environment has an important effect on the ESTI in the Beijing ECDA. This indicator shows the extent to which the water resources of Beijing's ECDA and the environment are being protected. The green coverage rate is an important indicator to measure the quality of the ecological environment. A high level of green coverage has a positive effect on the ESTI, while reductions of green coverage can threaten ESTI (Chen K et al., 2010; Li X et al., 2017). The comprehensive utilization of solid waste and the harmless treatment rate of household garbage are response subsystem factors that reflect the level of achievement of environmental protection efforts.

The development of a tourism economy has a significant impact on the indicators of ESTI in the Beijing ECDA. This impact need not be completely supportive or completely obstructive. The kind of impact depends on whether the development of the tourism industry is in harmony with ecological security. Total tourism revenue as a proportion of GDP, and the number of star-rated hotels are two performance indicators that reflect the developmental situation of the tourism industry. The steady development of the tourism industry during the years 2005-2014 led to an increase in the ESTI composite index. If the relationship between development of the tourism industry and ecological security is handled properly, the development of the tourism economy will have ecological compensation effects for the Beijing ECDA. This view is consistent with the results of Zhou B et al. (2015), Cao X et al. (2006) and Li X et al. (2017).

6 Discussion and policy recommendations

6.1 Discussion

A process of rapid urbanization and the sustained expansion of urban areas has reduced the amount of natural ecological space and led to grave environmental problems that seriously threaten ecological security (Deng J et al., 2017; Su Y et al., 2016). ECDAs play an important role in safeguarding the natural environment during the urbanization process. Based on the theory of major function-oriented zoning, some scholars divide ECDAs into spatial categories like country (Fan J et al., 2010 and 2012; Fan J and Li P, 2009; Fan J, 2015) or province (Zhang L, 2009). In recent years, environmental protection efforts and a focus on the rational exploitation and utilization of natural resources in the Beijing ECDA have been strengthened. Given the characteristics of environmental protection, the tourism industry has been identified as a leading industry for each sub-area in Beijing's ECDA. But rapid development of the tourism industry has put pressure on the ecological environment, and this has attracted the attention of many scholars (Gao J et al., 2015; Li Y and Jin L, 2014; Wang H et al., 2012). Some scholars propose that tourism ecological security refers to tourism development that does not cause irreversible changes to the ecological system where the development occurs and does not lead to the degradation or collapse of that system (Cao X et al., 2006; Dong X, 2003). Ecotourism is an environmentally friendly and alternative livelihoods industry, and the development of ecotourism can help local residents to choose jobs and promote sustainable social and economic development (Tang C et al., 2012). Therefore, it is particularly important to develop ecotourism as a way to protect ecological security protection in the Beijing ECDA.

There are limited studies focused on the evaluation of ESTI in ECDAs. Establishing a system of indicators for evaluating ESTI can help to ensure the sustainable development of the tourism industry in ECDAs. This paper uses a system of indicators for evaluating ESTI in ECDAs that takes into consideration economic factors, environmental factors, social factors and tourism industry factors. In contrast to the work of Zhou B et al (2015), the evaluation indicator system used in this paper pays more attention to social economic development and ecological environment protection factors. The improved TOPSIS method, the grade dynamic model of ecological security, the Markov model, and the gray relational grade model are used to examine ESTI of the Beijing ECDA in this paper. The methodology used by this study can enrich the theory of ecological security evaluations of the tourism industry.

There exist regional disparities in the quality of the tourism environment in Beijing (Mao X et al., 2016), and these are consistent with the regional disparities of spatial and temporal characteristics of ESTI found in this paper. The results show that the composite index of ESTI in Beijing's ECDA increased steadily during the years of the study. However, there is still much room for improvement. The improvement in the composite index of ESTI in Beijing's ECDA can be attributed mainly to work the Beijing government has done to maintain Beijing's ECDA as an ecological protection barrier and an area to conserve the city's water resources. The city government's planning uses policies, financing, ecological compensation mechanisms and other initiatives to promote ecological conservation and construction in Beijing's ECDA. The Beijing government is also committed to the principle of green development, and encourages local governments to develop rural tourism and folk tourism, leisure agriculture, and other types of ecotourism. The tourism industry is also a source of alternative livelihoods for residents of the Beijing ECDA.

Factors related to the ecological environment and the development of the tourism industry have an important impact on the ESTI in Beijing's ECDA. Factors such as the annual concentration of SO_2, the annual rate of increase of water replenishment in the ecological environment, the proportion of total tourism revenue to GDP, green coverage, and the number of star-rated hotels are all important. The reduction of green garden spaces, wetlands, nature reserve areas (Li X et al., 2017), and per capita green area (Chen K et al., 2010) threaten the ecological security of local tourism. These most significant indicators are mainly classified as natural environmental factors and tourism economic factors, classifications that are confirmed by Mao X et al., (2016), Han B et al., (2015) and He L et al., (2018).

6.2 Policy recommendations

In view of the critical security level of ESTI in the Beijing ECDA, this paper offers four suggestions to enhance the ecological security grade of the tourism industry in Beijing's ECDA. First, ecological civilization construction has become an important part of sustainable development in China, especially in ECDAs. Therefore, in the process of vigorously promoting the construction of ecological civilization, many environmental indicators of ESTI in the ECDA will be greatly improved. Second, planning for the Beijing ECDA should be developed systematically and include such items as ecological industry development plans, and environmental protection and construction plans. Third, a national environmental protection program should be implemented. Based on capital development goals and functional orientation, measures that take into consideration the following must be formulated: plans must take local conditions into consideration, reduce pressure on the environment, improve environmental status, enhance environmental response, and increase government investment support, financial transfer payments and ecological compensation. Fourth, the tourism industry in the sub-areas of Beijing's ECDA should take into consideration the characteristics of resources, ecology, environment, location and transportation systems in their sub-areas to develop green services such as eco-tourism, rural tourism, folk-custom tourism and leisure agriculture. The amount of land available for tourism services and infrastructure should be increased to promote the integration of tourism with other industries. Finally, coordination of the relationship between development of the tourism industry and the ecological security grade should be handled scientifically, and a mechanism for ecological compensation for tourism industry activities should be established. The economic benefits of tourism should be used to fund ecological security construction and environmental protection work and to provide ecological compensation for residents of the ECDA.

6.3 Limitations and future research directions

The research results in this paper can enrich the theory of ESTI and provide guidance for efforts to promote the sustainable development of ECDAs. This paper is, however, deficient in some respects. First, as other studies have done (Jin H et al., 2016; Yu F and Lu L, 2005), all of Changping and Fangshan districts were incorporated into our study area. This approach may lead to a higher ESTI index for the economic indicators and a lower ESTI index for the environmental indicators in the parts of Fangshan and Changping that are included in the Beijing ECDA. Second, there are many factors that can influence the ESTI, and the indicator system developed for this paper does not include all of the indicators that may influence ESTI. The indicator selection process should be based on the specific characteristics of the research objectives to ensure that the process is more objective. Third, we encountered difficulties collecting data for a study that covered a long period of time and a large physical area. We suggest that government agencies and institutions optimize the process of collecting, storing and making available relevant data sources, and enrich the data gathering process with technologies such as remote sensing. Fourth, additional empirical research on the indicator system for ESTI should be carried out in other ECDAs in the future. Fifth, because ESTI describes a long-term, dynamic phenomenon, a system for evaluating, monitoring and forecasting ESTI should be established. Sixth, the degree of coordination between ecological security and the sustainable development of the tourism industry in ECDAs should be increased in the future.

7 Conclusions

This paper constructs a system of indicators to evaluate ESTI in ECDAs. The paper uses improved TOPSIS method, the grade dynamic model for ESTI, the Markov chain, and the gray relational grade model to examine ESTI in the Beijing ECDA. The study analyzed the characteristics of the spatial and temporal evolution of ESTI and the main factors influencing the ESTI in Beijing's ECDA during the years 2005-2014. The research results show that:

(1) The ESTI composite index for the Beijing ECDA improved rapidly during the study period, but there is still great potential for more improvement in the future. (2) The ESTI in many sub-areas of Beijing's ECDA improved from grades II and III to grades IV and V, and there were strong fluctuations in ESTI grade levels during the period. (3) A gray relational grade model was used to calculate the gray correlation degree of the factors affecting ESTI in Beijing's ECDA. The main factors affecting ESTI were: the annual concentration of SO_2, the annual increase the water replenishment rate in the ecological environment, the proportion of total tourism revenue to GDP, green coverage, the number of star-rated hotels, the proportion of days in each year with air quality of level two or better, the solid waste comprehensive utilization rate, and the rate for the harmless treatment of garbage.

This study proposed a methodology based on a P-S-R-EES framework to evaluate the ecological security of the tourism industry ECDAs and the level of sustainable development at tourist destinations. After appropriate modifications, this methodology could be applied to other areas. The composite index of ESTI that this study presents could be used as a tool for tourism industry managers and decision-makers in the Beijing ECDA.

References

[1] Baabou, W., Grunewald, N., Ouellet-Plamondon, C., et al., 2017. The ecological footprint of Mediterranean cities: awareness creation and policy implications. *Environmental Science & Policy*. 69, 94-104.

[2] Cao, X., 2006. Ecological security evaluation of tourism destination based on ecological footprint analyses—a case of Kaifeng city. *China Population, Resources and Environment.* 16(2), 70–75. (in Chinese)

[3] Cao, X., Chen, T., Wang, W., 2006. Ecological security evaluation of tourism destination--a case of Kaifeng city. *Research of Soil and Water Conservation*. 13(2), 209-212.(in Chinese)

[4] Chai, S.T., Zhao, Q., 2009. On the optimum construction quantity of urban star hotel-A case study of Qingdao. *Journal of Qingdao Hotel Management College*, 1, 10-14. (in Chinese).

[5] Chen, K., Su, M., Li S., et al., 2010. The health assessment of the urban ecosystem of Xining city. *Geographical Research*. 29(2), 214-222. (in Chinese)

[6] Cheng, G., Yue, X., 2011. Research and Prediction of Ecological Security in Jiangsu Province Based on the Ecological Footprint. *Asian Agricultural Research*. 3(4), 48-53.

[7] Chu, X., Deng, X., Jin, G., et al., 2017. Ecological security assessment based on ecological footprint approach in Beijing-Tianjin-Hebei region, China. *Physics & Chemistry of the Earth Parts A/b/c*. DOI: 10.1016/j.pce.2017.05.001.

[8] Dai, F., Nan, L., Liu, G., 2010. Assessment of regional ecological security based on ecological footprint and influential factors analysis: a case study of Chongqing Municipality, China. *International Journal of Sustainable Development & World Ecology*. 17(5), 390-400.

[9] Deng, J.J., Chen, L.X., Yang, C.Y., et al., 2017. Significance evaluation of ecological corridor in a highly-urbanized areas: a case study of Shenzhen. *Geographical Research*. 36(3), 573-582.(in Chinese)

[10] Dong, X.W., 2003. Ecological security evaluation of tourist destinations——a case of Wudalianchi National Park. *Natural Science Journal of Harbin Normal University*. 19(6), 100-105. (in Chinese)

[11] Dong, X.W., 2004. Ecological security evaluation of Jingpohu National Park. *Territory & Natural Resources Study*. (2), 74-76. (in Chinese)

[12] Ezeonu, I.C., Ezeonu, F.C. 2000. The environment and global security. *The Environmentalist*. 20, 41–48.

[13] Fan, J., 2015. Draft of major function oriented zoning of China. *Acta Geographica Sinica*, 70 (2), 186-201.(in Chinese)

[14] Fan, J., Li, P.X. 2009. The scientific foundation of major function oriented zoning in China. *Journal of Geographical Sciences*. 19 (5), 515-531.

[15] Fan, J., Sun, W., Zhou, K., et al., 2012. Major function oriented zone: new method of spatial regulation for reshaping regional development pattern in China. *Chinese Geographical Science*. 22(02), 196-209.

[16] Fan, J., Tao, A.J., Ren, Q., 2010. On the historical background, scientific intentions, goal orientation, and policy framework of major function-oriented zone planning in China. *J. Resour. Ecol.* 1(4), 289-299.

[17] Farrell, B.H., Runyan, D., 1991. Ecology and tourism. *Annals of Tourism Research*. 18(1), 26-40.

[18] Feng, Y., Luo, G.P., Han, Q.F., et al., 2014. Evaluation of land use change degree and ecological security in the Manas River Basin, Xinjiang, China. *Russian Journal of Ecology*. 45(1), 46–53.

[19] Gao, J., Zhou, C.B., Wang, R.S., et al., 2015.Assessment and evaluation of tourism environmental carrying capacity in typical total scale tourism leisure city—a case study of Yanqing. *Ecological Economy*. 31(7), 101-105.(in Chinese)

[20] Gibbs, D., Longhurst, J., 1995. Sustainable development and environmental technology: a comparison of policy in Japan and the European Union. *The Environmentalis*t. 15, 196–201.

[21] Gong, J.Z., Liu, Y.S., Xia, B.C., et al., 2009. Urban ecological security assessment and forecasting, based on a cellular automata model: a case study of Guangzhou, China. *Ecol. Modell.* 220, 3612–3620.

[22] Gong, M., Fan, Z., Wang, J., et al., 2017. Delineating the ecological conservation redline based on the persistence of key species: Giant pandas (Ailuropoda melanoleuca) inhabiting the Qinling Mountains. *Ecological Modelling.* 345, 56-62.

[23] Gössling, S., Hansson, C. B., Horstmeier, O., et al., 2002. Ecological footprint analysis as a tool to assess tourism sustain-ability. *Ecological Economic.* 43(2-3), 199-211.

[24] Green, H., Hunter, C., 1992. The environmental impact assessment of tourism development. *In: Johnson, P., Thomas, B. (Eds.), Perspectives on Tourism Policy. Mansell, London.*

[25] Guo, F., 2008. Developing ecological industry in the capital ecological conservation area. *Social Science of Beijing*. 04(11), 36-41. (in Chinese)

[26] Han, B., Liu, H., Wang, R., 2015. Urban ecological security assessment for cities in the Beijing–Tianjin–Hebei metropolitan region based on fuzzy and entropy methods. *Ecological Modelling*. 318(24), 217–225.

[27] He, D., Liu, H., Xue, Z., 2010. Studies on the development of rural tourism of Beijing ecological conservation development area. *Chinese Journal of Agricultural Resources and Regional Planning*. 31(1), 43-46.(in Chinese)

[28] He, L., Shen, J., Zhang, Y., 2018. Ecological vulnerability assessment for ecological conservation and environmental management. *Journal of Environmental Management*. 206, 1115-1125.

[29] Hong, W., Jiang, R., Yang, C., et al., 2016. Establishing an ecological vulnerability assessment indicator system for spatial recognition and management of ecologically vulnerable areas in highly urbanized regions: a case study of Shenzhen, China. *Ecological Indicators.* (69), 540–547.

[30] Hong, W., Guo, R., Su, M., 2017. Sensitivity evaluation and land-use control of urban ecological corridors: a case study of Shenzhen, China. *Land Use Policy*. 62, 316–325.

[31] Huang, H., Chen, B., Ma, Z.Y., et al., 2017. Assessing the ecological security of the estuary in view of the ecological services– a case study of the Xiamen Estuary. *Ocean & Coastal Management*. 137, 12-23.

[32] Hunter, C., 2002. Sustainable tourism and the tourism ecological footprint. *Environment, Development and Sustainability.* 4, 7–20.

[33] Hunter, C., Shaw, J., 2007. The ecological footprint as a key indicator of sustainable tourism. *Tourism Management*. 28(1), 46-57.

[34] Hwang, C.L., Yoon, K., 1981. Multiple attribute decision making—methods and applications. *Heidelberg: Sprinter-Verlag*.

[35] Jia, T.F., Feng, Y.F., 2012. Ecological security assessment on tourism resources development in ecological fragile district: a case of Ordos, Inner Mongolia. *Journal of Arid Land Resources and Environment*. 26(5), 187-193. (in Chinese)

[36] Jin, H.R., Liu, S.H., 2016. Land use scenarios simulation in ecological conservation area: A case study of Miyun district, Beijing. *Ecological Economy*. 12(2), 102-111. (in Chinese)

[37] Jogo, W., Hassan, R., 2010. Balancing the use of wetlands for economic well-being and ecological security: the case of the Limpopo wetland in southern Africa. *Ecological Economics*. 69(7), 1569–1579.

[38] Jurado, E. N., Tejada, M. T., Garcia, F. A., et al. 2012. Carrying capacity assessment for tourist destinations. Methodology for the creation of synthetic indicators applied in a coastal area. *Tourism Management*. 33(6), 1337-1346.

[39] Kurniawan, F., Adrianto, L., Bengen, D. G., et al., 2016. Vulnerability assessment of small islands to tourism: The case of the Marine Tourism Park of the Gili Matra Islands, Indonesia. *Global Ecology & Conservation*. 6(C), 308-326.

[40] Li, J., Ren, Z., Zhou, Z., 2006. Quantitative analysis of the dynamic change and spatial differences of the ecological security: a case study of Loess plateau in northern Shaanxi Province. *Journal of Geographical Sciences*. 16(2), 251–256.

[41] Li, R., Wang, J., Cheng, K., 2010. Evaluation and optimization of ecological security in Yuntaishan scenic spot. *Journal of Beijing Forestry University (Social Sciences).,* 99(1), 71-75.(in Chinese)

[42] Li, S., Chen, Y., 2012. Assessment of ecological security of coastal wetland tourism in Shandong province. *Scientific and Technological Management of Land and Resources.* 29(4), 6-13. (in Chinese)

[43] Li, X., Liu, G., Wang, M., 2016. Is the Rising Proportion of Tertiary Industry Cost Disease or Structure Bonus?. *Statistical Research*. 7, 46-54. (in Chinese)

[44] Li, X., Wu, L., Wu, Q., 2017. Evaluation on tourism ecological security and diagnosis of its obstacle indicators in China. *Ecological Economy*. 33(6), 90-95. (in Chinese)

[45] Li, Y.J., Chen, T., Hu, J., et al., 2013. Tourism ecological security in Wuhan. *Journal of Resources and Ecology*. 4 (2), 149-156.

[46] Li, X.G., Wu, Q., Zhou, Y., 2017. Spatio-temporal pattern and spatial effect of Chinese provincial tourism eco-security. *Economic Geography*. 37(3), 210-217.(in Chinese)

[47] Li, Y.F., Sun, X., Zhu, X.D., et al., 2010. An early warning method of landscape ecological security in rapid urbanizing coastal areas and its application in Xiamen, China. *Ecological Modelling*. (221), 2251–2260.

[48] Li, Y.X., Jin, L.S., 2014. Research on characteristics and component of ecological footprint about rural tourism taking Liugou village, Yanqing County of Beijing as an example. *Resource development & Market.* 30(9), 1147-1152. (in Chinese)

[49] Li, Y.Y., 2011. The implementation way and policy measures of ecological compensation mechanism in Beijing ecological conservation area. *Journal of Central University of Finance & Economics.* (12), 75-80. (in Chinese)

[50] Li, Y.Z., Liu, Y., Yan, X.P., 2012. A DPSIR-Based indicator system for ecological security assessment at the basin scale. *Acta Scientiarum Naturalium Universitatis Pekinensis.* 48(6), 971-981. (in Chinese)

[51] Liao, C., Li, L., Yan, Z., et al., 2004. Ecological security evaluation of sustainable agricultural development in karst mountainous area. *Chinese Geographical Science*. 14(2), 142–147.

[52] Lin, D., 2012. Research on island tourism ecological security evaluation model based on the ecological footprints. *Journal of Neijiang Teachers College.* 27(12), 70-74,105.(in Chinese)

[53] Liu, C. L., Chen, M.X., Tang, Z.P., et al., 2014. The "valley economy" model of regional development: a case study of mountain areas in Beijing, Northern China. *Journal of Mountain Science.* 11(5), 1372–1382.

[54] Liu, H.M., 2013. The impact of human behavior on ecological threshold: Positive or negative?—Grey relational analysis of ecological footprint, energy consumption and environmental protection. *Energy Policy*. (5), 711–719.

[55] Liu, T.T., Zhang, B.X., 2009. Application of the fuzzy synthetically evaluation method to environmental quality study of tourism destinations—a case of Huairou District of Beijing. *Journal of Capital Normal University (Natural Sciences Edition)*. 30(3), 77-86.(in Chinese)

[56] Liu, X., Yang, Z.P., Di, F., et al., 2009. Evaluation on tourism ecological security in nature heritage sites—case of Kanas Nature Reserve of Xinjiang, China. Chin. *Geogra. Sci.* 19(3): 265–273.

[57] Liu, Y, Kong, F, Gonzalez, EDRS., 2017. Dumping, waste management and ecological security: Evidence from England. *Journal of Cleaner Production*. 167, 1425-1437.

[58] Lu, C.Y., Wen, F., Yang, Q.Y., 2011. An evaluation of urban land use performance based on the Improved TOPSIS method and diagnosis of its obstacle indicators: a case study of Chongqing. *Resources Science*. 33(3), 535-541. (in Chinese)

[59] Lu, J., 2007. The origin of tourism ecological security thought and its security status diagnosis. *Journal of Inner Mongolia Finance and Economics College.* (5), 38-38. (in Chinese)

[60] Lu, J., Chen, T., Liu, L.M., 2008. Analysis about Ecological Security System of Region Tourism Development—Taking "Gegentala Grassland Tourist Center of Siziwang Banner of Inner Mongolia" as an Example. *Progress in Geography*. 27(2), 80－88. (in Chinese)

[61] Luo, H., He, Z.W., 2015. Research on low-carbon rural-tourism evaluation based on DPSIR model---a case study of Mentougou in Beijing. *Science Technology and Industry*. 15(8), 118-126. (in Chinese)

[62] Ma, C., Wang, X.Y., Zhang, Y.X., et al., 2017. Emergy analysis of ecosystem services supply and flow in Beijing ecological conservation area. *Acta Geographica Sinica*. 72(6), 974-985. (in Chinese)

[63] Mao, X.R., Xiong, H.G., Zhu, Y.C., 2016. Comprehensive evaluation and analysis of county tourism environmental quality in Beijing city. *Areal Research and Development*. 35(1), 91-95. (in Chinese)

[64] Martín-Cejas, R.R, Sánchez, P.P.R., 2010. Ecological foot print analysis of road transport related to tourism activity: the case for Lanzarote Island. *Tourism Management*. 31(1), 98-103.

[65] McCool, S., 1994. Planning for sustainable nature dependent tourism development: the limits of acceptable change system. *Tourism Recreation Research*. 19 (2), 51-55.

[66] O'Reilly, A.M., 1986. Tourism carrying capacity—concept and issues. *Tourism Management*. 7, 254-258.

[67] Pu, Y.X., Ma, R.H., Ge, Y., et al., 2005. Spatial-temporal dynamics of Jiangsu regional convergence with spatial Markov Chains approach. *Acta Geographica Sinica*. 60(5), 817-826. (in Chinese)

[68] Qu, H., Xia, C.J., 2013. An Empirical Analysis on the Impact of Tourism Development on the Fiscal Revenue of China. *Journal of Beijing International Studies University*. 9, 23-28. (in Chinese)

[69] Rapport, D.J., Friend, A.M., 1979. Towards a comprehensive framework for environmental statistics: a stress-response approach. Statistics Canada = Statistique Canada, Ottawa.

[70] Rashid, A., Irum, A., Malik, I.A., et al., 2017. Ecological footprint of Rawalpindi: Pakistan's first footprint analysis from urbanization perspective. *Journal of Cleaner Production*. 170, 362-368.

[71] Ross, S., Wall, G., 1999. Ecotourism: Towards congruence between theory and practice. *Tourism Management.* 20, 123–132.

[72] Simon, F.J.G., Narangajavana, Y., Marques, D.P., 2004. Carrying capacity in the tourism industry: A case study of Hengistbury Head. *Tourism Management*. 25, 275–283.

[73] Su, M.R., Fath, B.D., 2012. Spatial distribution of urban ecosystem health in Guangzhou, China. *Ecological Indicators*. (15), 122–130.

[74] Su, Y., Chen, X., Liao, J., et al., 2016. Modeling the optimal ecological security pattern for guiding the urban constructed land expansions. *Urban Forestry & Urban Greening*. 19, 35-46.

[75] Subject Group of Beijing Municipal Committee of China Democratic League (SGBMCCDL), 2007. Study on the relationship between ecological-environmental improvement and industrial development in the ecological conservation region of Beijing. *Social Science of Beijing.* (6), 47-52. (in Chinese)

[76] Sun, C., Liu, Y., Tang, X.M., et al., 2016. The choice of leading industry based on functional orientation in the ecological conservation development area of Beijing. *Acta Scientiarum Naturalium Universitatis Pekinensis.* 52(6), 1085-1092. (in Chinese)

[77] Sun, J.R., 2018. Spatial-temporal characteristics and influencing factors of tourism economic density in Jiangsu province. *Modern Business Trade Industry*. 5, 12-14. (in Chinese)

[78] Sun, Y.J., Wang, R.S., 2000. Environment capacity of ecotourism resort. *Chinese Journal of Applied Ecology*. 11(4), 564–566. (in Chinese)

[79] Tang, C.C., Fan, W.J., Zhu, L., 2014. The discussion on development model of wetland ecotourism for Yeya lake in Beijing. *Ecological Economy*. 30(8), 132-134. (in Chinese)

[80] Tang, C.C., Liu, X.Q., Song, C.Y., 2016. Impact of haze on regional tourism industry and its countermeasures. *Geography and Geo-Information Science.* 32(5), 121-126. (in Chinese)

[81] Tang, C.C., Zhong, L., Cheng, S., 2013. A review on sustainable development for tourist destination. *Progress in Geography*. 32(6), 984-992. (in Chinese)

[82] Tang, C.C., Zhong, L.S., Chen, T., 2009. Characteristics of spatial differentiation and development modes for ecotourism resources in the Sanjiangyuan region. *Resources Science.* 31(11), 1825-1831. (in Chinese)

[83] Tang, C.C., Zhong, L.S., Cheng, S.K., 2012. Tibetan attitudes towards community participation and ecotourism. *Journal of Resources and Ecology.* 3(1), 8-15.

[84] Tang, C.C., Zhong, L.S., Fan, W.J., et al., 2015. Energy consumption and carbon emission for tourism transport in World Heritage Sites: a case of the Wulingyuan area in China. *Natural Resources Forum*. 39(2), 134-150.

[85] Tang, C.C., Zhong, L.S., Pin, Ng., 2017. Factors that influence the tourism industry's carbon emissions: a tourism area life cycle model perspective. *Energy Policy.* 109, 704–718.

[86] Tang, C.C., Zhou, Y.Y, He, Y.C., et al., 2017. Building rural eco-tourism pattern from the ecological civilization construction perspective. *Ecological Economy*. 33(4), 127-132. (in Chinese)

[87] Wang, G., Wang, J.L., Gong, L.Y., et al., 2013. Spatio-temporal evolution of regional ecological security based on GIS-Markov--a case study of Dalian Ganjinzi District. *Scientia Geographica Sinica.* 33(8), 957-964. (in Chinese)

[88] Wang, H., Wang, H., Sun H., et al., 2012. Assessment of the ecological security in the three gorges reservoir area by using the ecological footprint method. *Journal of Mountain Science*. 9(6), 891–900.

[89] Wang, L.J., Li, J.J., Chen, J.L., 2010.Spatial-temporal features of inter-province tourism in China. *Progress in Geography*. 29(10), 1249-1255. (in Chinese)

[90] Wang, L.L., Yu, H., Zhou, B., 2015. The coordination level of tourism and urban development in 25 major Chinese tourist cities. *Economic Geography*. 35(2), 195-203. (in Chinese)

[91] Wang, S., Meng, W., Jin, X., et al., 2015. Ecological security problems of the major key lakes in China. *Environmental Earth Sciences.* 74(5), 3825–3837.

[92] Wang, X., Yang, Q.Y., He, C.Y., et al., 2014. Lang ecological security evaluation of ecological conservation developmental areas based on P-S-R Model—a case study of Fengdu county, Chongqing. *Research of Soil and Water Conservation*. 21(3), 169-175. (in Chinese)

[93] Wang, X., Yuan, H., 2009. Research on the present situation and the development of ecological conservation area of Beijing. *CITY*. (9), 33-35.

[94] Wang, Y., 2012. Evaluation of tourism Ecological security in Mentougou district of Beijing. Doctoral dissertation. Beijing Second foreign Language College. Beijing, China. (in Chinese)

[95] Wei, Y., Huang, C., Lam, P.T.I., et al., 2015. Sustainable urban development: A review on urban carrying capacity assessment. *Habitat International.* 46, 64-71.

[96] Wu, C.Y., Guo, L.L., Yu, J.T., 2013. Dynamic simulation of regional tourism ecological security. *Systems Engineering*. 31(2), 94-99.

[97] Wu, X., Wu, Y.J., 2014. Evaluation on the Eco-safety of Mountainous City Based on Gray Correlation Model. *Resources and Environment in the Yangtze Basin*. 23(3), 385-391.

[98] Xiao, J.H., Yu, Q.D., Liu, K., et al., 2011. Evaluation of the ecological security of island tourist destination and island tourist sustainable development: a case study of Zhoushan Islands. *Acta Geographica Sinica*. 66(6), 842-852. (in Chinese)

[99] Xie, H., Yao, G., Liu, G., 2015. Spatial evaluation of the ecological importance based on GIS for environmental management: A case study in Xingguo county of China. *Ecological Indicators*. 51, 3–12.

[100] Xiong, H.Q., Li, X.G., Jiang, W.H., et al., 2003. Study on measures of ecological safety of the exploitation of tourism in Wulong County. *Chong Qing Environmental Science*. 2003, 25(5), 16-18.(in Chinese)

[101] Xu, M., Liu, C.L., Li, D., et al., 2017.Tourism ecological security early warning of Zhangjiajie, China based on the improved TOPSIS method and the grey GM (1,1)model. *Chinese Journal of Applied Ecology*. 28(11), 3731-3739. (in Chinese)

[102] Xu, M., Zhu, X., Zhou, J., 2012. Analysis of land ecological security pattern of Hunan province based on catastrophe theory. *Journal of Natural Disasters*. 21(6), 199-207.(in Chinese)

[103] Xue L., Ren Z.Y., 2011. The spatial-temporal dynamics of Guanzhong eco-security based on spatial Markov Chains. *Ecology and Environmental Sciences*. 20(1), 114-118.

[104] Yang, C.Y., 2009. New exploration research of reasonable threshold of tourism environment carrying capacity based on the Complex System Theory. *China Population Resources and Environment.* 19(3), 163-168. (in Chinese)

[105] Yang, Q., Liu, G., Hao, Y., et al., 2018. Quantitative analysis of the dynamic changes of ecological security in the provinces of China through emergy-ecological footprint hybrid indicators. *Journal of Cleaner Production*. 184, 678-695.

[106] Yang, Z.Q., Zhang, Z.M., 2014. Dynamic evaluation of tourism ecological security based on PSR Model. *Journal of Fujian Forestry Science and Technology*. 41(1), 159-165. (in Chinese)

[107] Yin, J., Zheng, X., 2017. Safety Assessment and Security Pattern of Industrial Ecosystem of Tourism of the Yangtze River Economic Zone. *East China Economic Management*. 31(4), 60-65. (in Chinese)

[108] Yu, F.L., Huang, Z.F., Cao, F.D., et al., 2014. The influence of urbanization on the development of tourism economy in China. *Journal of Natural Resources*, 8, 1297-1309. (in Chinese)

[109] Yu, F.L., Lu, L. 2005. Research on the characteristics and development strategy of tourism market of urban water source—Taking Miyun county as an example. *Inquiry Into Economic Issues*. (10), 71-75.(in Chinese)

[110] Yu, K.J., 1999. Landscape ecological security patterns in biological conservation. *Acta Ecologica Sinica*. 19(1), 8–15. (in Chinese)

[111] Yuan, S.Q., Wang, R., Han, J., et al., 2010. The model of under-forest economy suited for ecological conservation area—a case of Huairou district in Beijing. *Food and Nutrition in China*. (11), 26-29. (in Chinese)

[112] Zhao, Y., Zou, X., Chen,g H., et al., 2006. Assessing the ecological security of the Tibetan plateau: Methodology and a case study for Lhaze County. *Journal of Environmental Management*. 80, 120–131.

[113] Zhang, F., Liu, X., Zhang, J., 2017. Ecological vulnerability assessment based on multi-sources data and SD model in Yinma River Basin, China. *Ecological Modelling*. 349, 41–50.

[114] Zhang, J.F., Yang H., Zuo, R.H., et al., 2016. The development of the sightseeing leisure agriculture in the ecological conservation area of Beijing: A case study of Baoshan Town, Huairou District in Beijing. *Chinese Journal of Agricultural Resources and Regional Planning.* 37(6), 218-223.(in Chinese)

[115] Zhang, J.H., Zhang, J., Wang, Q., et al., 2008. Measuring the ecological security of tourist destination: Methodology and a case study of Jiuzhaigou. *Geographical Research*. 27(2), 449-458. (in Chinese)

[116] Zhang, J.Q., Wu, Y.J., Ge, Y., et al., 2014. Eco-security assessments of poor areas based on gray correlation model: A case study in Enshi. *Geographical Research*. 33(8), 1457-1466. (in Chinese)

[117] Zhang, P., Qiu, P., 2014. Evaluation and trend analysis of tourism ecological security in karst areas: A case study for Guangxi. *Carsologica Sinica.* 33(4), 483-489. (in Chinese)

[118] Zhang, L., 2009. Beijing mountain functional zoning and relative policies. *Economic Geography*. 29(6), 989-994. (in Chinese)

[119] Zhang, M., Liu, Y. M., Wu, J., et al., 2018. Index system of urban resource and environment carrying capacity based on ecological civilization. *Environmental Impact Assessment Review.* 11(2), 90-97.

[120] Zheng, Y.X., Xue, F., Zhang, Z.G., 2015. Ecological security measurement using the IRDS model in forest scenic spots. *Resources Science*. 37(12), 2350-2361. (in Chinese).

[121] Zhong, X., Liu, S., Wang, X., et al., 2010. Research of ecological security on the Tibet Plateau. *Journal of Mountain Science*. 28 (1), 1-10.

[122] Zhou, B., Zhong, L., Chen, T., et al., 2015. Spatio-temporal pattern and obstacle factors of ecological security of tourism destination: a case of Zhejiang Province. *Scientia Geographica Sinica.* 35(5), 599-607. (in Chinese)

[123] Zhou, B., Yu, H., Zhong, L.S., et al., 2016. Developmental trend forecasting of tourism ecological security trends: the case of Mount Putuo Island. *Acta Ecologica Sinica*. 36(23), 7792-7803.(in Chinese)

[124] Zhou, B., Zhong, L.S., Chen, T., et al., 2015.Ecological security early-warning in Zhoushan Islands based on variable weight model. *Chinese Journal of Applied Ecology*. 26(6), 1854-1862. (in Chinese)

[125] Zhou, D.Q., 2011. Division of government and market based on tourism ecology security. *Economic Geography*. 31(3), 514-517. (in Chinese)

[126] Zou, J.H., Zhao, Y.H., Wang, H.Q., 2008. Study on tourism ecological security in China. *Journal of Xiangtan Normal University (Social Science edition)*. 30(1), 74-76. (in Chinese)

Figures

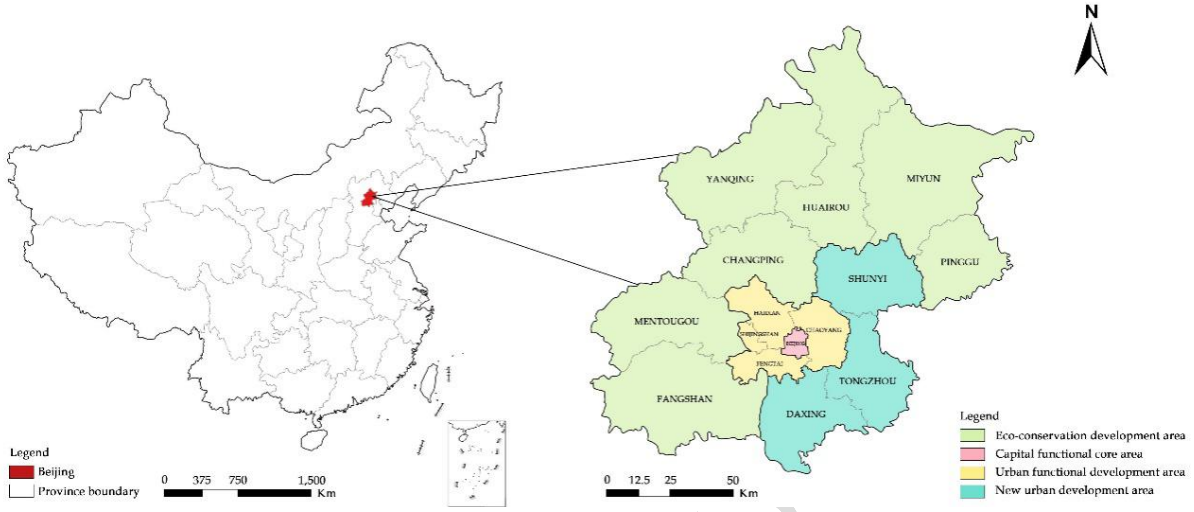

Figure 1. Beijing's ECDA sub-areas

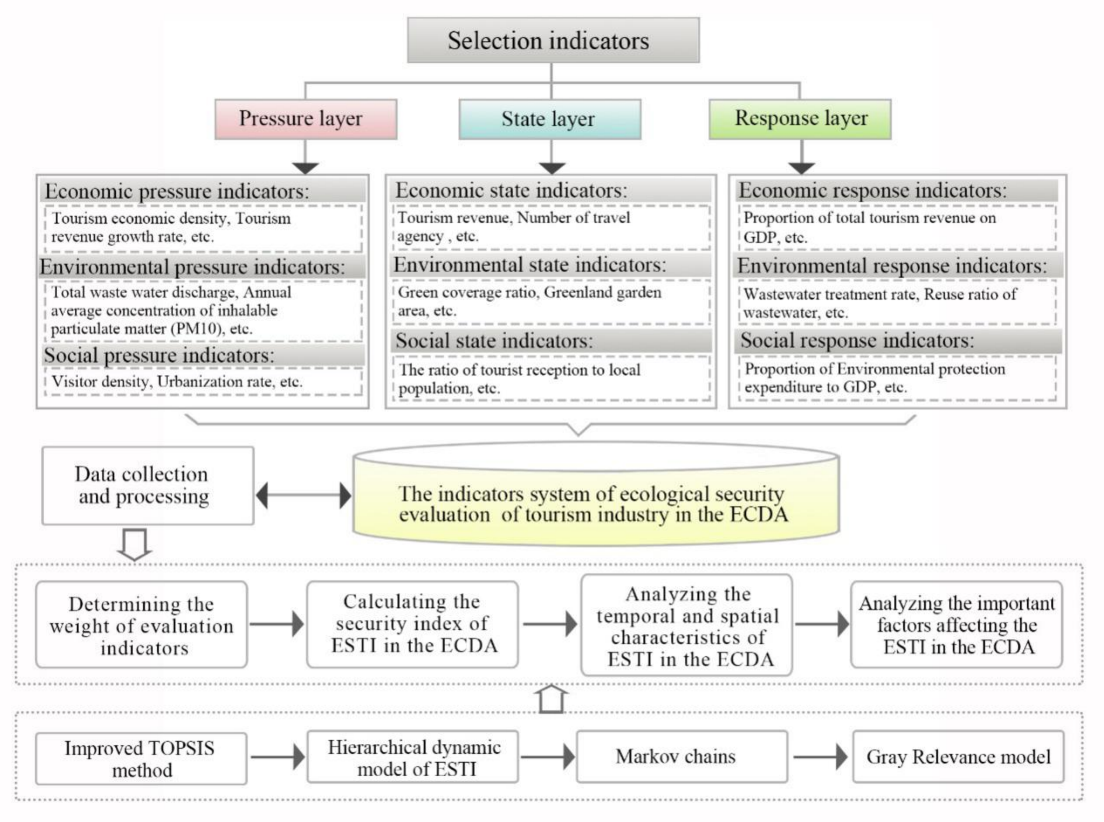

Figure 2. The framework for evaluating ESTI in the ECDA

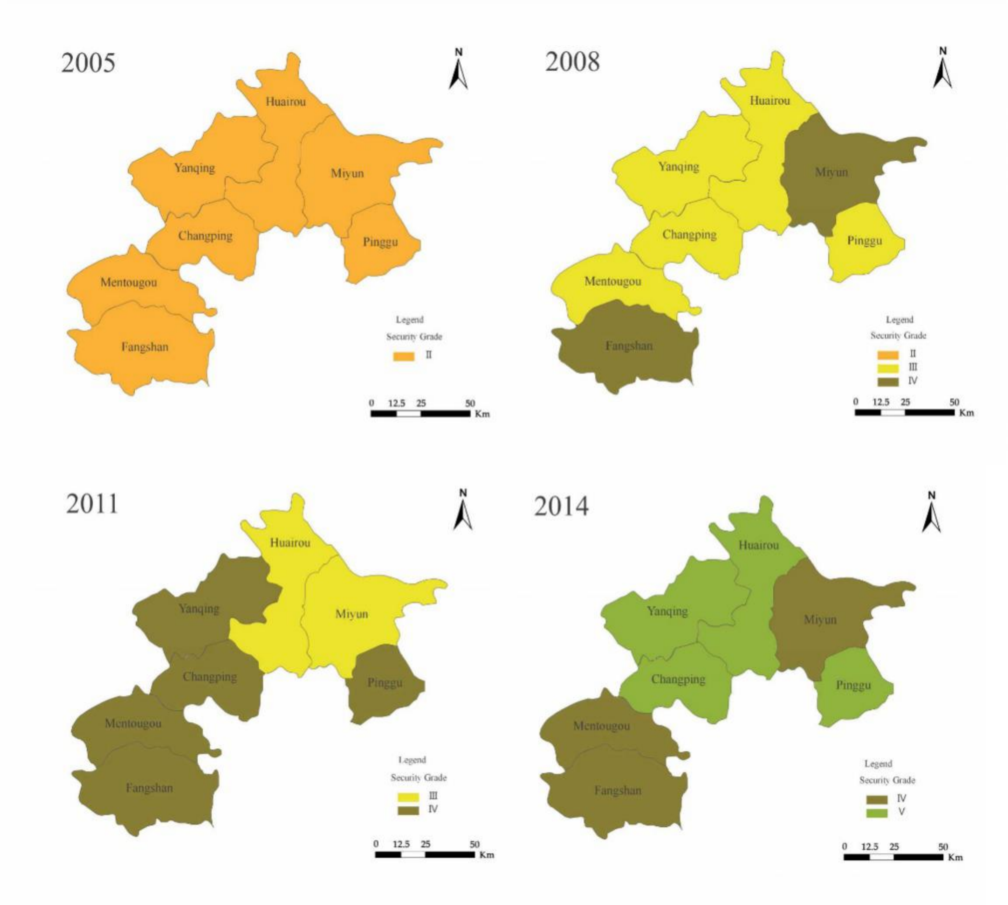

Figure 3. Spatial variation of ESTI grades in Beijing's ECDA from 2005 to 2014

Tables

Table 1 Summary of relevant research achievement on ESTI

Authors	*Journal*	Study area	Model	Method	Dimension	Indicator
Xiao J et al.(2011)	*Acta Geographica Sinica (in Chinese)*	Zhoushan Islands, China	Ecological footprint	The ecological footprint	The background ecological footprints of islands, Tourism ecological footprints of islands	Tourism transport footprint, Tourism accommodation footprint, etc.
Zhou B et al.(2015)	*Scientia Geographica Sinica (in Chinese)*	Zhejiang Province, China	P-S-R-EES	The improved TOPSIS method, Markov chains, Gray relational grade model	Economics, Environment, Society	Tourism economic density, Domestic tourism revenue growth rate, etc.
Li X et al.(2017)	*Economic Geography (in Chinese)*	China Provinces	P-S-R-EES	Spatial autocorrelation analysis	Economics, Environment, Society	Domestic tourists growth rate, International tourists growth rate, etc.
Zhang P and Qiu P (2014)	*Carsologica Sinica(in Chinese)*	Guangxi's karst area	PSR	Comprehensive index method and entropy method	Economics, Environment, Society	Karst landscape area ratio, Nature reserve coverage, etc
Kurniawan et al.(2018)	*Global Ecology & Conservation*	Marine Tourism Park of the Gili Matra Islands, Indonesia	—	Remote sensing analysis, Comparison study	Coastline changes, Coral reef area changes, Live coral area changes, Development area	Coastline changes, Coral reef area changes, Live coral area changes, Development area

Table 2 Indicators for evaluating ESTI in the ECDA based on the P-S-R-EES framework

First-level indicator	Second-level indicator	Third-level indicator	Unit	References	Attribute	Relation	Weight
Pressure	Economic pressure	Tourism economy density D1	Ten thousand/km^2	Sun J (2018)	N	E	0.0296
		Tourism revenue growth rate D2	%	Wang Y et al. (2015)	N	E	0.0222
		Service industry growth rate D3	%	Li X et al.(2016)	N	P	0.0183
	Environmental pressure	Total amount of waste water discharge D4	Ten thousand ton	Zhou B et al., (2015)	-	C	0.0327
		Annual average concentration of inhalable particulate matter (PM10) D5	%		-	C	0.0260
		Annual average concentration of SO_2 emission D6	mcg/m^3	Zhou B et al. (2015)	-	C	0.0236
		Annual average concentration of NO_2 emission D7	mcg/m^3		-	C	0.0209
		Solid waste discharge D8	Ten thousand ton	Zhou B et al. (2015)	-	C	0.0289
		Daily water consumption per capita D9	Ten thousand ton		-	C	0.0301
		Days with National Ambient Air Quality Standard Class II accounted for the proportion of the whole year D10	%		+	C	0.0277
	Social pressure	Visitor density D11	per/km^2	Gao J et al.(2015)	N	E	0.0233
		Visitor growth rate D12	%		N	E	0.0212
		Urbanization rate D13	%	Yu F et al.(2014)	N	P	0.0208
State	Economic state	Tourism revenue D14	Ten thousand	Chai S et al.(2009)	N	E	0.0296
		Number of travel agencies D15			N	E	0.0208
		Number of star hotels D16			N	E	0.0292
		Number of folklore tourism operatorsD17			N	E	0.0234
		Economic density of lodging enterprises D18	/		N	E	0.0282
		Number of scenic tourist spots D19			N	E	0.0286
		Folklore tourism economic density D20	/		N	E	0.0253
		Number of sightseeing gardens D21		Mo Zhang et al., (2018)	+	E	0.0233
	Environmental state	Green coverage ratio D22	%		+	C	0.0250
		Greenland garden area D23	hm^2	Zhou B et al., (2015)	+	C	0.0219

		Number of gardens D24			+	P	0.0242
		Per capita green area D25	m^2	Zhou B et al., (2015)	+	P	0.0210
		Per capita park green area D26	hm^2		+	P	0.0211
	Social state	Ratio of tourist arrivals to local population D27	/	Zhou B et al.,	N	E	0.0252
		Number of tourism practitioners D28	Per	(2015)	N	E	0.0227
Response	Economic response	Proportion of total tourism revenue to GDP D29	%	Zhou B et al.,	N	P	0.0339
		Proportion of service industry revenue to GDP D30	%	(2015)	N	P	0.0203
		Proportion of fiscal revenue to GDP D31	%	Qu H. et al., (2013)	N	P	0.0281
	Environmental response	Wastewater treatment rate D32	%		+	C	0.0238
		Reuse ratio of wastewater D33	%		+	C	0.0241
		Harmless treatment rate of household garbage D34	%	Zhou B et al.,	+	C	0.0255
		Comprehensive utilization rate of solid waste D35	%	(2015)	+	C	0.0295
		Proportion of nature reserves to urban areas D36	%		+	C	0.0243
		Annual growth rate of ecological environment replenishment D37	%		+	C	0.0283
		Energy consumption decline rate of RMB ten thousand GDP D38	%		+	C	0.0254
	Social response	Proportion of environmental protection expenditure to GDP D39	%		+	C	0.0208

Note: (1) + indicated positive index, − indicated reverse index, N indicated neutral. (2) E indicated that the indicators entirely caused by tourism; P indicated that the indicators partially caused by tourism; C indicated that the indicator be closely related to the development of tourism industry.

Table 3 The grades of ESTI in the ECDA

Security index	0<A≤0.3	0.3<A≤0.4	0.4<A≤0.5	0.5<A≤0.6	0.6<A≤0.7	0.7<A≤0.8	0.8<A≤1.0
Security Grade	I	II	III	IV	V	VI	VII
Security situation	Deterioration	Risk	Sensitive	Critical Security	General Security	Relative Security	Extreme Security

Table 4 Subsystem security indexes for ESTI in Beijing's ECDA from 2005 to 2014

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Pressure	0.374	0.318	0.382	0.495	0.449	0.586	0.533	0.551	0.549	0.522
State	0.224	0.278	0.294	0.332	0.364	0.482	0.537	0.625	0.696	0.764
Response	0.488	0.492	0.541	0.538	0.441	0.528	0.534	0.453	0.417	0.457

Table 5 The ESTI composite index of the Beijing's ECDA from 2005 to 2014

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Evaluation value	0.361	0.359	0.409	0.463	0.419	0.533	0.535	0.543	0.551	0.582
ESG	Ⅱ	Ⅱ	Ⅲ	Ⅲ	Ⅲ	Ⅳ	Ⅳ	Ⅳ	Ⅳ	Ⅳ

Note: ESG stands for ecological security grade. Ⅱ indicates that ecological security grade of the tourism industry was risk, Ⅲ sensitive, Ⅳ critical security, and Ⅴ general security.

Table 6 Markov matrix of transfer probabilities for ESTI grades the Beijing's ECDA from 2005 to 2014

ESG	2005-2008				2008-2011				2011-2014			
	Ⅱ	Ⅲ	Ⅳ	Ⅴ	Ⅱ	Ⅲ	Ⅳ	Ⅴ	Ⅱ	Ⅲ	Ⅳ	Ⅴ
Ⅱ	0	0.714	0.286	0	0	0	1	0	0	0	0	0
Ⅲ	0	0	0	0	0	**0.2**	0.8	0	0	0	0.5	0.5
Ⅳ	0	0	0	0	0	0.5	**0.5**	0	0	0	**0.4**	0.6
Ⅴ	0	0	0	0	0	0	0	0	0	0	0	0

Note: EEG indicates eco-security grade. Ⅱ indicates that ecological security grade of the tourism industry was risk, Ⅲ sensitive, Ⅳ critical security, and Ⅴ general security.

Table 7 Gray correlation degree between ESTI and influencing factors from 2005 to 2014

Indicators	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14
Correlation degree	0.589	0.427	0.423	0.573	0.493	**0.655**	0.454	0.523	0.507	**0.606**	0.468	0.440	0.438	0.589
Rank	11	36	37	17	30	1	33	24	27	6	32	34	35	10
Indicators	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24	D25	D26	D27	D28
Correlation degree	0.500	**0.607**	0.579	0.547	0.565	0.575	0.599	**0.608**	0.596	0.523	0.524	0.472	0.510	0.549
Rank	28	5	14	20	18	16	9	4	12	23	22	31	26	19
Indicators	D29	D30	D31	D32	D33	D34	D35	D36	D37	D38	D39			
Correlation degree	**0.614**	0.514	0.500	0.582	0.402	**0.601**	**0.605**	0.536	**0.654**	0.567	0.399			
Rank	3	25	29	13	38	8	7	21	2	15	39			