Chin. Geogra. Sci. 2020 Vol. 30 No. 5 pp. 776–790
https://doi.org/10.1007/s11769-020-1145-9

Springer Science Press
www.springerlink.com/content/1002-0063

Spatial Pattern and Influencing Factors of Regional Ecological Civilisation Construction in China

DU Yan[1], QIN Weishan[1, 2], SUN Jianfeng[1], WANG Xiaohui[1], GU Haoxin[1]

(1. *School of Resource and Environment Engineering*, *Ludong University*, *Yantai* 264025, *China*; 2. *Institute of Geographic Sciences and Natural Resources Research*, *Chinese Academy of Sciences*, *Beijing* 100101, *China*)

Abstract: Ecological civilisation construction is a strategy for regional sustainable development based on a regional system of human-land relations. The comprehensive measurement and regional differentiation in construction levels are the key issues of ecological civilisation construction. This study aims to build 35 index systems that coalesce on four aspects: ecological economic adjustment and operation, ecological and social development and progress, ecological resources and environmental security, and ecological institutional and cultural awareness. We measured and evaluated the level of ecological civilisation construction of 329 cities (prefecture-level cities, autonomous prefectures and leagues) in 2018 using a comprehensive evaluation system and a spatial autocorrelation method to assess spatial differences in the level of ecological civilisation construction across China. This approach takes 'the humanities-economic geography' comprehensive perspective and uses a GWR (geographically weighted regression) model to analyse 10 influencing factors. Results show that: 1) the level of ecological construction can be divided into five types: higher, high, medium, low, and lower levels, according to the evaluation score. The five types are spindle-shaped in quantity and there is a significant imbalance in their spatial distribution, mainly trending from the southeast coast to the northwest. The land is decreasing, and the southern region is higher in level than the northern region. 2) The results of the spatial autocorrelation method show obvious spatial differences in ecological civilisation construction across China and that the level of ecological civilisation construction is positively autocorrelated. From east to west, the hot zone gradually transitions to a cold zone. A high-high type is mainly distributed in eastern coastal cities of China, and the number of high-low and low-high types are small. The low-low type is mainly distributed in the northwestern and northeastern regions. 3) The effect of influencing factors is heterogeneous in their spatial distribution, and the abundance of ecological resources is the most influential factor. According to the main influencing factors, each region should adhere to the principle of differentiation according to local conditions when choosing its ecological civilisation construction path and establishing an assessment mechanism. This study provides a scientific basis for enriching the regional level measurement of ecological civilisation construction, clarifying the current level of ecological civilisation construction in China, and implementing the regional differentiation path of ecological civilisation construction.

Keywords: construction of ecological civilisation; spatial autocorrelation; spatial pattern; geographically weighted regression (GWR); China

Citation: DU Yan, QIN Weishan, SUN Jianfeng, WANG Xiaohui, GU Haoxin, 2020. Spatial Pattern and Influencing Factors of Regional Ecological Civilisation Construction in China. *Chinese Geographical Science*, 30(5): 776–790. https://doi.org/10.1007/s11769-020-1145-9

1 Introduction

Since entering the 21st century, the concept of ecological civilisation has become more widely recognised, and gradually entered the official discourse system. Xi Jinping proposed at the 19th National Congress of the

Received date: 2019-12-23; accepted date: 2020-04-14
Foundation item: Under the auspices of National Social Science Foundation of China (No. 19CGL070)
Corresponding author: QIN Weishan. E-mail: weishan93@126.com

Communist Party of China (CPC) that building ecological civilisation is an important component of the millennial plan for China's sustainable development. The concept of ecological civilisation has become a research hotspot from all levels of theory and practice (Fan et al., 2013). After more than ten years of development, China has formed a complete construction system for an ecological civilisation. This system was implemented at the town, city, and zone ordinances, and it achieved remarkable results. However, it is difficult to transform and promote the construction of ecological civilisation in many regions of China.

In recent years, academia, has conducted a lot of research on the construction of ecological civilisation. The main research focus is on the theory of ecological civilisation (Gu et al., 2013; Xiao and Zhao, 2017; Hansen M H et al., 2018), the path toward constructing ecological civilisation (Fritz and Koch, 2016; Mi et al., 2018; Xin, 2019), and so on. Many scholars mainly interpret ecological civilisation from the perspective of economics (Pelletier, 2010; Söderbaum, 2015) through which they explore the implementation path of constructing ecological civilisation (Schneider et al., 2010). At present, researches on the construction of ecological civilization in China mainly includes two parts: 1) scientific connotation, theoretical basis and significance of ecological civilization. Some scholars have defined different connotations of ecological civilization based on different subject backgrounds. Liao et al. interpreted the connotation of ecological civilization from the perspectives of nature, values, production methods, and lifestyle (Liao and Zhang, 2011). Zhang believes that ecological civilization is a higher-level form of civilization covering political, economic, social, and environmental levels (Zhang, 2019). With the deepening of research, the depth and breadth of the connotation of ecological civilization have expanded and gradually integrated into the entire process of political, economic, social, and cultural construction. 2) Evaluation and analysis of ecological civilization construction level. Based on different understandings of the connotation of ecological civilization, scholars evaluate the level of ecological civilization construction at different spatial scales and types. The study of ecological civilisation on the macro-scale mainly focuses on the provincial administrative units and evaluates the level and efficiency of construction at the national level (Li and Xi, 2016; Wang et al., 2018; Wang and Chen, 2019), or it takes the provincial or urban agglomerations as examples to explore the spatio-temporal process of construction in a single region (Zhu et al., 2010; Zhang et al., 2020), thus, revealing its driving mechanisms. In contrast, most micro-scale studies discuss the level and optimisation path of constructing ecological civilisation in a single city (Yu et al., 2015; Zhang et al., 2015; Zhang et al., 2017). The evaluation objects of ecological civilisation has involved marine (Zhang et al., 2019), water (Xiang et al., 2018), urban (Liu et al., 2019), and population development (Zhang and Zhang, 2011). Most research methods use quantitative measures, and an increasing number of scholars are using a comprehensive evaluation index system for the level of ecological construction from the perspective of different disciplines (Dryzek and Stevenson, 2011; Zhang et al., 2016). Qin, for example, constructed an evaluation system for ecologically-civilised cities that rated on a scale from one to five (Qin et al., 2013). He built an indicator system based on the concept of a 'pressure-state-response' (PSR) and conducted empirical research on Changsha City of Hunan Province, China (He et al., 2011). Ma established a five-law collaborative evaluation model that includes economic, social, environmental, human settlements and transportation (Ma, 2009). Combining relevant research literatures, we can see that although the construction of various indicator systems has similarities and differences, they have considered the role of economic construction, social development, and political system in the construction of ecological civilization to a certain extent.

Despite previous results, we believe that regional differences in the construction of ecological civilisation are still hot issues and that China needs recognise these differences when promoting ecological civilisation. Cities are epicentres of ecological construction. By focusing on cities, we can reveal the regional variation in the level of ecological civilisation construction more scientifically and intuitively. However, the existing research at the national level has been settled by the provincial administrative units. There are few administrative units at the prefecture level that evaluate the spatial differences in characteristics of all hierarchical administrative units, including autonomous prefectures and leagues. Based on this, we try to summarize the characteristics of China's ecological civilization construction in 2018 from the perspective of prefecture-level administrative

units. The purpose is to clarify the current status quo of China's ecological civilisation construction, including the spatial distribution of its characteristics and causes. It also provides a scientific basis for further optimizing the development pattern of land space, for promoting the implementation of differentiated ecological civilisation, and for improving relevant laws and regulations.

2 Data and Method

2.1 Study area

China was the first country in the world to propose the construction of ecological civilisation and put it into the constitution. Provinces are continuously recommending the construction of ecological civilisation. However, China has a vast geographical area, with high terrain in the west and low in the east, forming three steps, complicated topographic and geomorphic units and diverse climatic types. The natural environment foundation is different among the regions, and the social and economic development is quite different too. There is a significant difference in the level of ecological civilisation construction. Taking the administrative divisions of 2018 as a standard, we selected 329 prefecture-level cities and above in China as our research area. This study does not include Hong Kong, Macao and Taiwan of China, and eight prefectures such as Da Hinggan Ling, Ali, Hotan, Kashgar, Tacheng, Altay, Aksu and Naqu region. Due to the particularity of Hainan Province, only Haikou and Sanya are studied. This paper divided the whole study area into six significant spatial regions from macroscopic district scale (Fig. 1).

2.2 Data

The data of all cities in the index system are derived from statistical data. Among these data include the total amount of water resources per capita; water consumption per 10 000 yuan (RMB) of GDP (Gross Domestic Product), which is derived from the *Water Resources Bulletin* of all provinces (MWRC, 2018). We refer to the list of national ecological civilization construction demonstration zones to calculate the proportion of demonstration zones to administrative divisions. Other data are calculated directly or indirectly from the *China City Statistical Yearbook* (NBSC, 2018) and the *China Regional Economy Statistical Yearbook* (NBSC, 2018) and the *Statistical Yearbook* of some provinces, municipalities, and autonomous regions (http://www.cnstats.org/). Some missing data were obtained by interpolation or trend analysis to ensure a scientific and objective result.

2.3 Methods

2.3.1 Concept definition and research framework

The report to the 18th National Congress of the CPC pointed out that 'to build an ecological civilisation, in essence, is to build a resource-conserving and environment-friendly society based on the carrying capacity of resources and the environment, guided by the laws of nature and aimed at sustainable development'. The description reveals the essence of constructing ecological

Fig. 1 Administrative divisions of China

civilisation, that is, to construct under the premise of respecting and protecting nature, and to recognise the comprehensive development of the economy and society and the dynamic balance and stability of ecological environments. Ecological civilization embodies the harmonious symbiotic relationship between human and nature. It is an inevitable stage of the development of modern civilization and is integrated into all aspects of economic construction, cultural construction, and social construction. Its construction content includes economic ecological civilization, social ecological civilization, environmental ecological civilization, and cultural ecological civilization (Fig. 2).

2.3.2 Constructing an indicator system

The construction of ecological civilization involves many aspects of social economic and ecological environment. The construction content must take into consideration the coordination of economic operation, social development, environmental protection and cultural construction. This article is based on the four-in-one ecological civilization construction path, with reference to the national ecological civilization construction demonstration city and county construction indicators, the Ministry of Construction's comprehensive construction of a well-off society in 2020, and other relevant indicator systems. We constructed an indicator system from four aspects: ecological economic adjustment and operation, ecological social construction and progress, ecological resources and environmental security and ecological institutional and cultural awareness (Table 1).

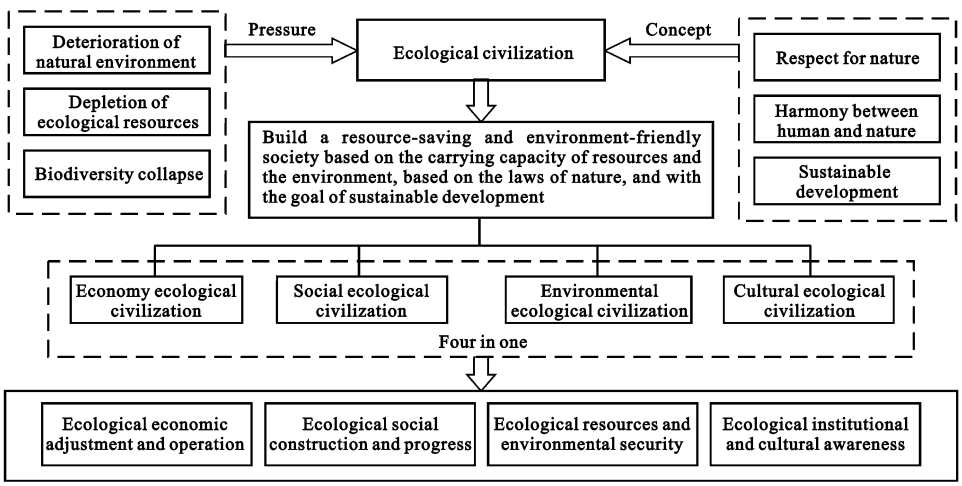

Fig. 2 Framework of ecological civilization construction

Table 1 China's ecological civilisation construction level evaluation index system

Criteria layer	Sub-criteria layer	Indicator layer	Weights
Ecological economic adjustment and operation	Economic structure optimization	Average GDP growth rate in the past three years	0.0761
		The added value of the service industry accounts for the proportion of regional GDP	0.1218
		Number of listed companies	0.1101
	Economic ecological development	Gross average production value	0.1228
		Unit GDP energy consumption	0.1472
		Unit GDP water consumption	0.0974
	Economic innovation development	Contribution rate of scientific and technological progress	0.1219
		Research and development expenditure as a percentage of GDP	0.0865
		The proportion of science and technology expenditure to fiscal expenditure	0.1161
Ecological social construction and progress	Livability	Per capita fixed assets investment	0.0781
		Beds for medical institutions per thousand population	0.1666
		Per capita road area	0.1463
		Number of students in general institutions of higher education in ten thousand	0.1502
		Education expenditure as a share of fiscal expenditure	0.1098

Continued **Table 1**

Criteria layer	Sub-criteria layer	Indicator layer	Weights
Ecological social construction and progress	Urban and rural coordinated development	Urbanization rate	0.1492
		Urban and rural per capita disposable income ratio	0.1090
		Urban-rural Engel coefficient ratio	0.0908
Ecological resources and environmental security	Ecological resource abundance	Total water resources per capita	0.0482
		Per capita ecological land area	0.1272
		Number of scenic spots above level 4A	0.1118
		Per capita public green area	0.1009
	Ecological environment governance	Green coverage rate in built-up areas	0.0746
		Harmless treatment rate of domestic garbage	0.0902
		Urban sewage treatment rate	0.0914
		Unit industrial output value air pollutant emissions	0.0538
	Ecological environment background	The proportion of fine weather day	0.0841
		Forest cover rate	0.1163
		The proportion of nature reserves in the area under the jurisdiction	0.1015
Ecological Institutional and cultural awareness	Institution building and investment	Proportion of national-level ecological civilization construction demonstration zones in administrative divisions	0.1898
		The proportion of energy conservation and environmental protection expenditure to fiscal expenditure	0.1624
		Environmental information disclosure rate	0.1611
	Social and cultural awareness	Per capita public library collection	0.1453
		Green trip rate	0.1276
		Invention patents per 10000 people	0.1162
		Quantity of material cultural heritage and intangible cultural heritage	0.0976

Note: GDP is Gross Domestic Product

2.3.3 Comprehensive evaluation and spatial analysis method

(1) Principal component analysis (PCA)

PCA is a dimensionality reduction method (Wold et al., 1987). In simple terms, it transforms N-dimensional data into orthogonal k-dimensional data to determine the weight of the evaluation index ($k < N$). In order to eliminate the influence of the data dimension difference on the calculation results, the original data is first standardized. The standardized data is subjected to principal component analysis, and the weights of each evaluation index are obtained. The index weights of each level are normalized, and the evaluation values of ecological civilization construction level are obtained by weighted summation with standardized data.

$$T_i = \sum_{j=1}^{n} E_{ij} U_{ij} \tag{1}$$

In the formula, T_i is evaluation value of level of ecological civilization construction in research unit i, E_{ij} represents the weight of the evaluation index, and U_{ij} represents the score of indicator j.

(2) Global spatial autocorrelation analysis

Global spatial autocorrelation is a common method for analyzing spatial clustering conditions throughout an area. The study is widely used in a variety of spatial patterns (Bebber D, 1999), this paper uses the Moran's I index for measurement:

$$I = \frac{\sum_{k=1}^{n}\sum_{j=1}^{n}(X_k - \overline{X})(X_j - \overline{X})}{S^2 \sum_{k=1}^{n}\sum_{j=1}^{n} W_{kj}} \tag{2}$$

where X_k and X_j represent the attribute values of element k and element j, $\overline{X}$ is its mean value, W_{kj} represents the spatial weight matrix, and S^2 represents the sample variance. Moran's I ranges from –1 to 1. When the value I tends to 1, it indicates that there is a spatial positive correlation. When the value I tends to –1, it indicates that there is a spatial negative correlation. When the value I is equal to 0, it means no spatial autocorrelation. Statistical analysis of Moran's I results using Z values:

$$Z(I)=\frac{1-E(I)}{\sqrt{var(I)}} \tag{3}$$

where $E(I)$ is the expected value and $var(I)$ is the coefficient of variation.

(3) Local spatial autocorrelation analysis

The Getis'G index is used to analyze the cold hotspot of the horizontal spatial pattern of ecological civilization construction, to more intuitively reflect the degree of spatial factor aggregation. Its calculation formula is:

$$G_i^*(d)=\frac{\sum_{k=1}^{n}\sum_{j=1}^{n}W_{kj}(d)X_j}{\sum_{j=1}^{n}X_j} \tag{4}$$

Standardize $G_i^*(d)$:

$$Z(G_i^*(d))=\frac{G_i^*(d)-E(G_i^*(d))}{\sqrt{Var(G_i^*(d))}} \tag{5}$$

where $E(G_i^*(d))$ and $Var(G_i^*(d))$ respectively represent the mathematical expectation and variance of $G_i^*(d)$, if $Z(G_i^*(d))$ is positive and significant, indicating that the value of the adjacent space of the position i is relatively high, and is a high-value space agglomeration, and vice versa, a low-value space agglomeration. According to the Getis'G index, the spatial agglomeration types can be divided into four types: hot spot area, subhot spot area, subcold spot area, and cold spot area (Getis and Ord, 2008).

(4) Geographically weighted regression (GWR)

Different from the general global regression model, the 'overall situation' estimation of parameters, the geographically weighted regression model can realize the variation of the coefficients of different regional regression models with the spatial location changes by embedding the spatial structure relationship of data (Brunsdon et al., 1998). Calculation formula as follows:

$$y_i=\beta_0(u_i,v_i)+\sum_{k=1}^{p}\beta_k(u_i,v_i)x_{ik}+\varepsilon_i \tag{6}$$

where y_i represents the dependent variable, x_{ik} represents the independent variable, β_0 represents the constant term, u_i,v_i is the coordinates of the ith sample point (e.g., latitude and longitude), and $\beta_k(u_i,v_i)$ is the kth regression parameter of the ith sample point. ε_i represents the error term.

3 Results and Discussion

3.1 Spatial distribution of ecological civilization construction level in China

3.1.1 Regional differences of ecological civilization construction level

The levels of ecological civilisation construction in different cities are uneven. Shenzhen has the highest level of ecological civilisation construction in China, with a score of 2.1662, followed by Beijing. The levels of ecological civilisation construction in resource-based cities are generally low. The Bortala Mongolian Autonomous Prefecture in Xinjiang has the lowest level with a score of 0.8166, The average level of ecological civilisation construction in China is 1.3479, which is equivalent to that of Taizhou City. According to the Jenks natural fracture method, the levels of ecological civilisation construction are divided into the following five categories: higher, high, medium, low, and lower (Fig. 3). The level of ecological civilisation construction in China has gradual differences between the eastern and western regions. The levels of ecological civilisation construction in the eastern coastal areas are generally high. The horizontal distribution of ecological civilisation construction in the central region is relatively random across all five construction levels, but it still reflects a transition from east to west; the level of ecological civilisation construction in the western region is generally low. Among the provinces, Zhejiang has the highest average level of ecological civilisation construction and Xinjiang has the lowest. The level of ecological civilisation construction decreases by region from East China to Northwest: East China > Central and South China > Southwest China > North China > Northeast China > Northwest China. The level of ecological civilisation construction in the south is generally better than that of the north.

From the perspective of the five construction levels, the higher-level areas of ecological civilisation construction include 24 cities, including Shenzhen, Beijing, and Shanghai, accounting for only 7.3% of the evaluation units. This indicates that the level of ecological civilisation construction in China still needs to be

strengthened at this stage. Among the higher-level cities, except for the five inland provincial capital cities of Xi'an, Chengdu, Guiyang Changsha and Zhenzhou, the rest are located on the eastern coast and are clearly situated on the Yangtze River Delta. After decades of construction and development, these areas have entered an important transition period of social and economic development. The high-level includes 67 cities, such as Yantai in Shandong Province and Hefei in Anhui Province, which accounts for about 20.4% of the evaluation units. They are mainly concentrated in the eastern coastal areas, including most cities in Shandong, Fujian, and Zhejiang provinces, and also include the western cities, such as Karamay in Xinjiang, Ordos in Inner Mongolia, and Kunming in Yunnan. These regions have a good economic base, resource and environmental advantages, and have deep development potential. They should be key areas for further promoting the construction of ecological civilisation in the future. The medium-level areas include 105 cities or regions, such as Chongqing Municipality and Shijiazhuang City. They are densely distributed in Central and South China. The low-level includes 98 cities, such as Anshan in Liaoning Province and Kaifeng in Henan Province, which are mainly distributed in North China, Inner Mongolia, and the Northeast Old Industrial Zone; they comprise the largest number of evaluation units. The lower-level areas include 35 cities, such as Neijiang in Sichuan Province and Luohe in Henan Province which are mainly distributed in the arid regions of the northwest and the Qinghai-Tibet Plateau. The common features among the low-level cities are fragile ecological environments and slow social and economic development. As a whole, the distribution of the five levels of ecological civilisation construction shows obvious regional differences. The provincial capitals generally have higher levels of ecological civilisation construction. The gap between the southern and northern regions is mainly reflected in the medium and lower construction levels.

3.1.2 Spatial distribution of subsystem construction level

From the perspective of the four subsystem construction levels (Fig. 4), the ecological economic operation and adjustment level shows an unbalanced spatial pattern with large differences between the east and west. In general, the upper and higher horizontal regions are associated with the spatial distribution of major urban agglomerations. The lower-level areas are mainly distributed in the central and western regions. The Dabie Mountains, Yanshan-Taihang Mountain Area, Daliang Mountains and Liupan Mountain Area, *etc*., particularly lack the proper local conditions for economic development and have weak economic foundations. It is necessary to provide further policy support. The higher-level regions are relatively scattered spatially, including the eastern coastal cities like Suzhou and Hangzhou as well as the resource-based cities in the central and western regions, such as Karamay and Ordos. These regions

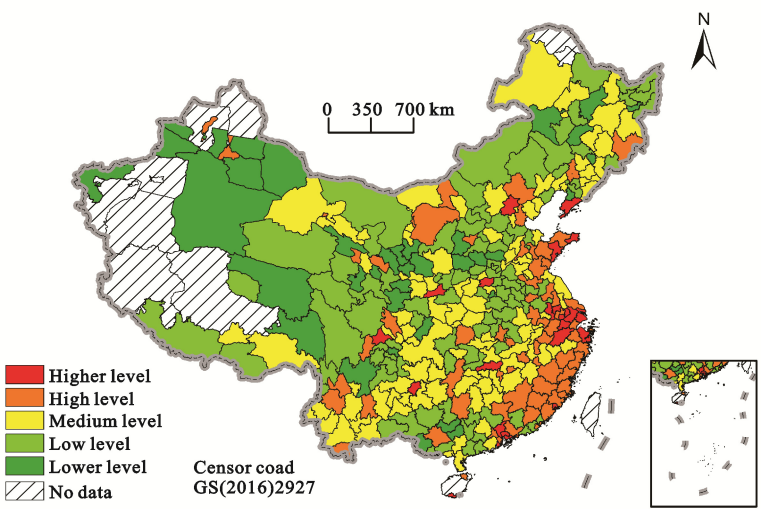

Fig. 3 The spatial distribution pattern of China's ecological civilisation construction level in 2018

scored more prominently in per capita fixed asset investment, urban-rural disposable income ratio, and urban-rural Engel coefficient ratio. The construction of a national ecological society shows good progress. The proportion of the medium-level and above areas exceeded 80%. Most of the urban infrastructure construction was relatively perfect, but the overall performance gradually decreased from east to west. The level of construction of ecological resources and environmental security systems is roughly marked by a north-south difference of about 30°N. Most of the south has reached a high level, and showing a significant high-value concentration in the southeast hilly areas. As one of the earliest experimental areas of ecological civilization, Fujian Province is at the forefront of the country in terms of ecological environment management and ecological resource protection. The construction level in the northern region is relatively poor. The northern and northwestern China is not particularly optimistic. There is an urgent need to raise the awareness of ecological and environmental protection and adhere to the long-term development of environmental protection and rational use of resources as strategic projects. A sound institutional system fundamentally guarantees the construction of an ecological civilisation. The inheritance and protection of culture is conducive for raising the awareness of basic literacy and the ecological protection of citizens and for promoting the connotative development of ecological civilisation. China's ecological institutional and cultural awareness system construction levels are generally good, and most areas are gradually establishing a sound ecological civilisation protection system. The higher-level areas are distributed in various groups throughout the country. This is a reasonable result given the recent establishment of ecological civilisation pilot and demonstration zones in various parts of the country.

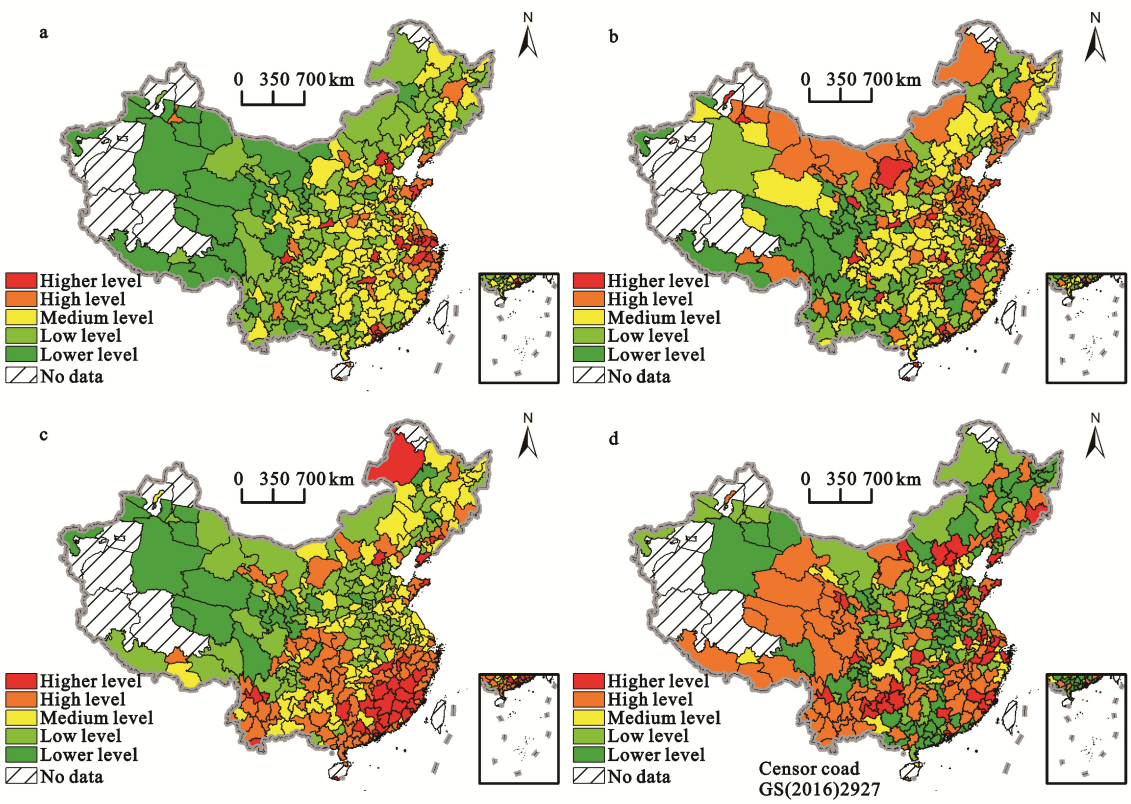

Fig. 4 China's ecological civilization subsystem construction level in 2018. a. ecological economic adjustment and operation; b. ecological social construction and progress; c. ecological resources and environmental security; d. ecological institutional and cultural awareness

3.2 Characteristics of spatial agglomeration of ecological civilization construction in China

We used ArcGIS software to calculate the overall Moran's *I* for the level ecological civilisation construction. For China, the Moran's *I* index was 0.2234. This shows that there is a significant spatial correlation in the level of ecological civilisation construction in China (Fig. 5); that is, the evaluation units with similar levels of ecological civilisation construction are spatially distributed.

Local spatial autocorrelation analysis shows that the spatial differentiation of China's ecological civilisation construction is obvious. There are 100 hotspot evaluation units, all located east of the Weifang (in Shandong)-Beihai (in Guangxi) line. These are high-level-distributed areas for ecological civilisation construction in China. There are 130 sub-hot spot evaluation units and 46 sub-cold spot units, basically representing the agglomeration status of lower construction levels. A total of 53 evaluation units are cold-spot units, mainly distributed as clusters in Northeast China, the Loess Plateau, and Northwest China, and are low-level areas for ecological civilisation construction.

Beside, we made a LISA (local indicators of spatial association) map based on a scatter plot of the Moran's *I* index (Fig. 6), which further illustrated the spatial distribution pattern of China's ecological civilisation construction levels. The results show that, at the significant level of 5%, the levels of ecological civilisation construction in China are spatially differentiated. The H-H (High-High) type is mainly distributed in the eastern coastal regions, L-L (Low-Low) type is mainly in the west and northeast regions, and the number of H-L (High-Low) and L-H (Low-High) locations are small.

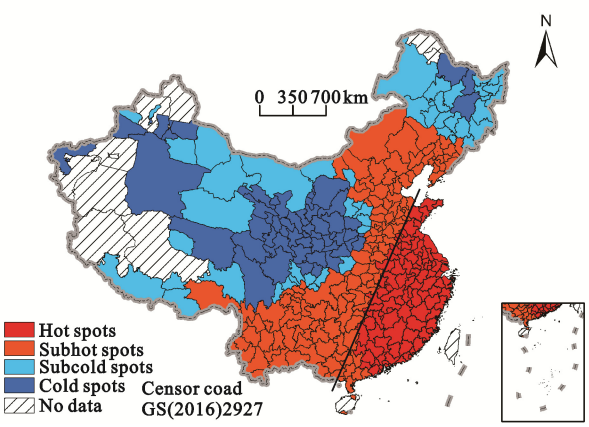

Fig. 5 Hotspots of China's ecological civilisation construction in 2018

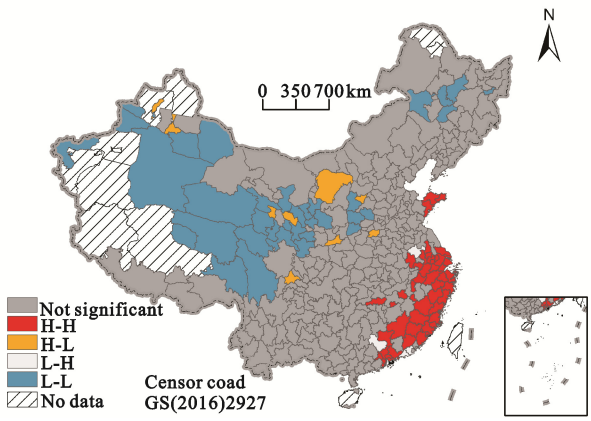

Fig. 6 Distribution of LISA (local indicators of spatial association) in China's ecological civilisation construction level in 2018

The H-H type indicates that the construction of ecological civilisation in adjacent areas is relatively high. They are mainly located in the eastern region, including Zhejiang and Fujian provinces, and some cities in Shandong, Jiangsu, Anhui, Hubei, Jiangxi, and Guangdong provinces. These areas have good local conditions, high levels of economic development, have accumulated capital and technology in an early stage, and have a relatively high degree of economic synergy and integration between regions. The government in these areas have also invested heavily in infrastructure construction, ecological environment management, and improving people's living standards, making these areas more advantageous in ecological civilisation construction. In the future, these areas should strengthen the strong alliance between cities, promote the overall improvement in the level of regional ecological civilisation construction, and play a leading role at the national level.

The H-L type indicates that the level of ecological civilisation construction in the adjacent areas is negatively correlated; that is, the level of ecological civilisation construction in the adjacent areas is lower than that in the area. There are not many cities of this type and they are mainly distributed in the central and western regions. There are nine cities in this type, including Chengdu, Xi'an, Ürümqi, and Erdos, *etc*., all of which are provincial capitals or economic centres. They have a good level of ecological civilisation construction, and they play a role in demonstrating the process of regional ecological civilisation construction. However, a polarisation effect is obvious, and there is a clear imbalance in

the development of the surrounding areas. In the future, they should actively strengthen regional cooperation and promote to improve the level of ecological civilisation construction in surrounding areas on the basis of solid construction achievements.

The L-H type indicates that the level of ecological civilisation construction in the region is lower than that in the adjacent areas, which including Chuzhou in Anhui Province and Qingyuan, Shanwei and Jieyang in Guangdong Province. There is a gap between the level of ecological civilisation construction and that of the surrounding areas, leading to the emergence of depressions in the construction of ecological civilisation. In the future, these cities needs to make full use of location advantages, establish a sense of alignment, actively learn from and draw on the advanced experience and capital technology of high-level areas nearby, and promote the development of high-quality and efficient ecological civilisation.

The L-L type indicates that the level of ecological civilisation construction in adjacent areas is generally low, and all of them are cold-spot units. They can be roughly divided into the western and northeastern economically-fragile regions. The common features among L-L type cities in the western region is a poor economic developmental foundation, a backward production model, a relatively fragile ecological environment, and functional zoning that is developmentally restricted. It is key for the nation to encourage policies that would lend continuous support into the future and that would improve infrastructure construction and people's living standards. The main common feature of L-L type cities in Northeast China is that the industrial structure is single. The local economic development is essentially carried out around the main state-owned enterprises of traditional industries. The resource dependence of industrial development is strong, and the ecological environment is destroyed. In recent years, the economic development has declined. Northeast China should actively change their concept of development, eliminate their resource dependence on economic development, foster new economic growth poles, and further strengthen the intensive use of ecological resources to curb the destructive trend of the ecological environment. These changes will eventually improve the quality of ecological civilisation construction.

3.3 Influencing factors of ecological civilization construction in China

3.3.1 GWR calculation result of impacting factors

According to our research, economy, society, environment and culture will affect the improvement of the level of ecological civilization construction. We have revised the evaluation index system of the level of ecological civilization construction and integrated 35 evaluation indicators into 10 impact factors, namely: economic structure optimization, economic ecological development, economic innovation development, livability, urban and rural coordinated development, ecological resource abundance, ecological environment governance, ecological environment background, institution building and investment, social and cultural awareness. We use 10 impact factors as independent variables and the level of ecological civilization construction as the dependent variable, and uses GWR tools in ArcGIS to conduct a geographically weighted regression analysis and explore the impact of different factors on the level of ecological civilisation construction. The operation results are shown in Table 2 and Fig. 7. The correlation coefficient of the regression analysis is 0.9562, and the fit of the effect is good. Based on median estimates of the parameters in the GWR regression, the most relevant factors in explaining the level of ecological civilisation construction are ecological resource abundance, followed by economic innovation development factors, economic structure optimisation factors, and social and cultural awareness factors, *etc*. The most irrelevant are the factors of urban and rural coordinated development.

3.3.2 Spatial heterogeneity analysis of influencing factors

(1) Ecological economic operation and adjustment

The operation and adjustment of an ecological economy include three indicators: economic structure optimisation, economic ecological developmentand economic innovation development. The coefficient of the economic structure operation factor generally declines from the southwest to northeast (Fig. 7a). The higher-value areas are mainly concentrated in Xinjiang, Tibet, Shaanxi, Sichuan, and other regions. The imbalance of urban economic development in these areas is relatively strong, and the difference in ecological construction level is greatly affected by economic structure optimisation factors. The coefficient of the economic ecological

Table 2 Estimates for the level of ecological civilization construction in GWR (geographically weighted regression) model

Influencing factors	Min	Quartile (25%)	Median	Quartile (75%)	Max
Economic structure optimization	3.84464	4.00252	4.07574	4.12832	4.24683
Economic ecological development	2.33452	2.46143	2.51074	2.62164	2.77834
Economic innovation development	3.85514	4.06204	4.17653	4.30826	4.34715
Livability	2.97624	3.06245	3.16842	3.32168	3.39754
Urban and rural coordinated development	1.81726	1.85627	1.88314	1.91486	1.96243
Ecological resource abundance	4.83526	5.27362	5.51624	5.82260	6.10623
Ecological environment governance	3.70324	3.80537	3.86267	3.93974	4.11056
Ecological environment background	2.73726	2.81334	2.82671	2.86483	2.94726
Institution building and investment	2.30824	2.33637	2.34726	2.36216	2.38268
Social and cultural awareness	3.59564	3.67824	3.97162	4.14628	4.45124
R^2			0.94332		
Adjusted R^2			0.94244		
AICc			–892.42167		
Bandwidth			4823813.43537		

development factor presents a spatial pattern that gradually increases from the lower reaches of the Yellow River Basin, such as in Shandong and Henan, to the surrounding areas (Fig. 7b). The unreasonable development and utilisation of ecological resources restricts the improvement in the level of ecological civilisation construction. The economic innovation development factor coefficient gradually increases from the west to northeast (Fig. 7c). The higher-value areas are mainly concentrated in North and Northeast China. The western region lacks the necessary economic foundation and has a harsh natural environment. The impact of science and technology on economic development is limited. On the contrary, the technological drive of economic development in the southeastern coastal areas is generally at a high level, and the ecological civilisation construction has less dependence on economic innovation and development factors. As a whole, the level of ecological civilisation construction in the northeastern, north China, and western regions are significantly affected by economic operation and adjustment. The western regions should promote the coordinated development of inter-regional economic construction. The north China should promote the ecologicalization of economic development, focusing on the economical use and reasonable development of ecological resources. The northeastern region should focus on optimizing their industrial development model and improving the scientific and technological content of economic construction.

(2) Ecological society construction and progress

The construction and progress of ecological society include two indicators: livability, and urban and rural coordinated development. The impact of livability of life on the level of ecological civilization construction is expressed as a spatial situation of ‘one extremely high and two extremely low’ (Fig. 7d), The high value areas include the northeast and north China, and the low poles appear in the southeast coastal area and the northwest inland area, which shows that in the northeast and north China, strengthening the construction of urban supporting facilities and improving the living environment provide a stronger impetus for promoting the construction of ecological civilization ; the coefficient of urban-rural synergy development is distributed in the central and western regions in a north-south direction (Fig. 7e), For the western region, due to the relatively backward urban development, the coordinated development between urban and rural areas has relatively little impact on the construction of ecological civilization, but in the northeast and southeast coastal areas, the level of urban and rural coordinated development is an important factor affecting the construction of ecological civilization. In general, the problems of human settlements brought about by urbanisation in Northeast and North China and the binary opposition between urban and rural areas are relatively serious, the construction of an ecological society should be strengthened to promote the sharing of the achievements of ecological civilization.

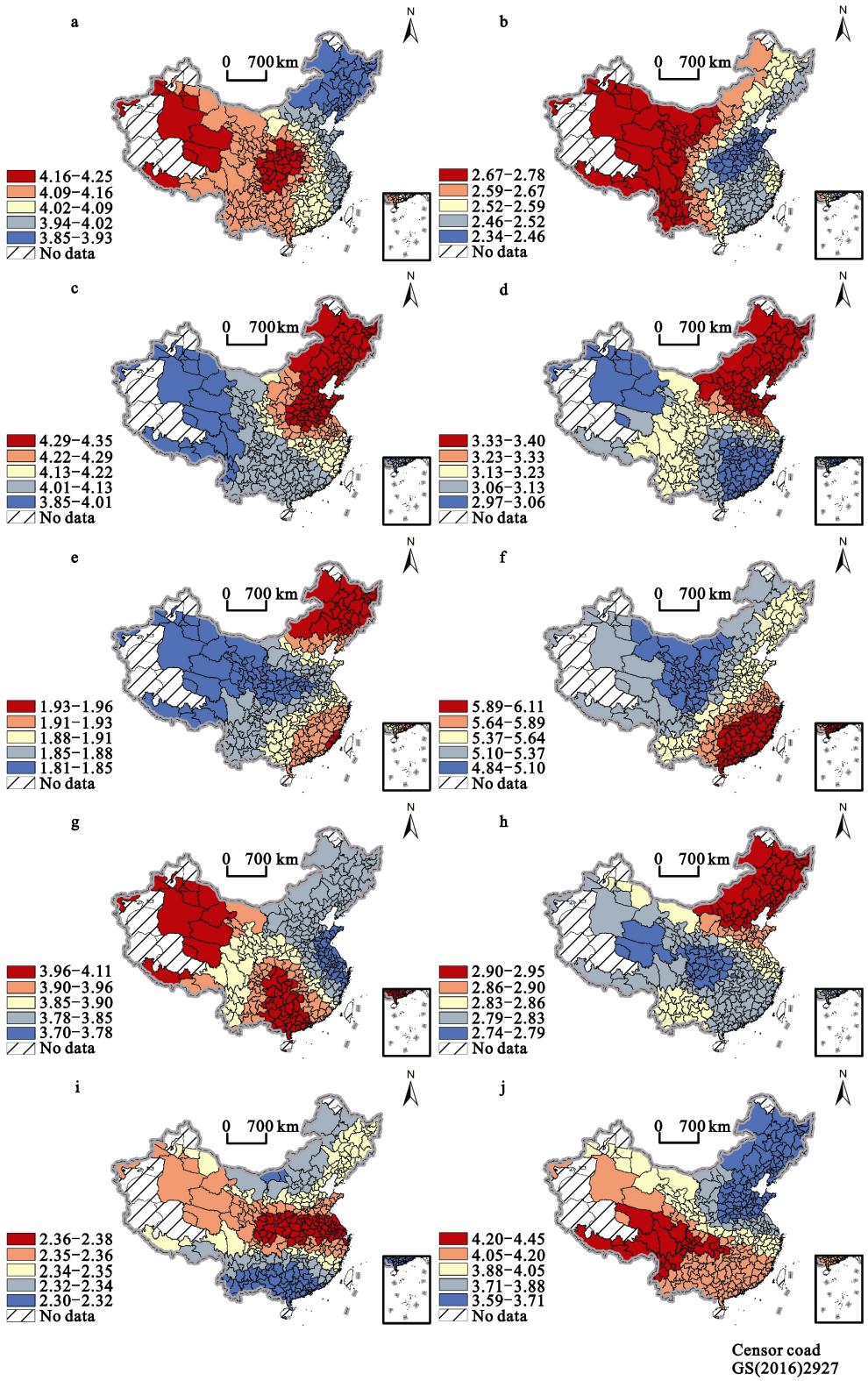

Fig. 7 Spatial pattern of coefficient for each evident factor under GWR model in 2018. a. economic structure optimization; b. economic ecological development; c. economic innovation development; d. livability; e. urban and rural coordinated development; f. ecological resource abundance; g. ecological environment governance; h. ecological environment background; i. institution building and investment; j. social and cultural awareness

(3) Ecological resources and environmental security

Ecological resources and environmental security include three indicators, ecological resource abundance, ecological environment background and ecological environment governance. The abundance factors have the most significant impact on the level of ecological civilisation construction. The factor's regression coefficients gradually increase from the northwestern regions, such as Gansu, Shaanxi, and Inner Mongolia, to the surrounding areas (Fig. 7f). The ecological resources in the northwestern region are relatively scarce, and the construction of ecological civilisation is more dependent on the rational exploitation and utilisation of ecological resources rather than the resources themselves.In terms of the ecological environment background, the regression coefficients increase from Sichuan and Qinghai to the surrounding circles (Fig. 7g). The higher-value area mainly falls in the northeastern region, and the ecological civilisation construction in this area has a strong dependence on the ecological environment foundation. The impact of eco-environmental governance on the level of ecological civilisation construction is more significant than that of the eco-environmental background. The distribution of factor coefficients is generally higher in the west and lower in the east, and higher in the south and lower in the north (Fig. 7h). The higher-value areas mainly appear in the northwestern regions, such as Xinjiang and Qinghai, as well as in the southwestern regions, like Guangxi and Guizhou. The improvement in the ecological environment has a strong effect on promoting the level of ecological civilisation construction in the region.

(4) Ecological Institutional and cultural awareness

Ecological Institutional and cultural awareness include two indicators: institution building and investment, social and cultural awareness. The institution building and investment factor coefficients overall show a strip-like distribution pattern that decreases from the central to the north-south direction in space (Fig. 7i). Most cities in southern China have established a relatively complete system of ecological civilisation construction. The ecological civilisation construction relies relatively little on policy support and input factors, while the establishment of some urban ecological civilisation construction systems in Shaanxi, Anhui, Henan, and other regions is still in its infancy. The government's insufficient attention is an important factor and leads to regional differences in the level of ecological civilisation construction. The coefficient of social and cultural awareness factor presents a spatial trend that gradually decreases from southwest to northeast (Fig. 7j). High-value areas are mainly concentrated in the south, especially Qinghai, Tibet and other upper and middle reaches of the Yangtze River. These areas are important ecological conservation areas in China. Raising awareness of ecological civilization construction is an important task to promote local ecological civilization construction.

4 Conclusions

This study evaluated the national ecological civilization construction level system at the level of prefecture-level units in 2018, and on this basis, divided the regional construction level differences and analyzed the influencing factors. Result comprehensively reflects the current level, spatial difference, and influencing mechanisms of ecological civilisation construction in China. The main theoretical value of this paper is to put forward a four-in-one ecological civilization construction system and construct a scientifically feasible evaluation system at the level of prefecture-level units. The practical significance is to provide guidance and basis for national and local governments to promote the high-quality construction of ecological civilization. The main conclusions of this article are as follows:

In 2018, China's ecological civilisation construction level shows obvious regional differences in spatial distribution, and gradually decreases from the eastern coast to the northwest inland. The southern region is slightly better than the northern region and the eastern region is better than the western region. Level of ecological civilisation construction in China can be divided into five types. There are a total of 24 prefecture-level units in the higher level area, which are basically composed of the main urban agglomerations in the eastern coastal areas such as the Yangtze River Delta, the Pearl River Delta, and inland provincial capitals. There are 67 prefecture-level units in the high level, mainly concentrated in the eastern region. A total of 105 prefecture-level units at a medium level concentrated in Central China and South China. There are 98 prefecture-level units in the low level, mainly distributed in the central and northern regions and the old industrial bases in Northeast China. There are 35 prefecture-level units in the lower level areas. The agglomera-

tion characteristics in the arid regions of the northwest and the Qinghai-Tibet Plateau are more obvious.

Ecological civilisation construction in China shows obvious spatial correlation, the results of local spatial autocorrelation evaluation show that the spatial pattern of a gradual transition from the southeast to the northwest from the hot spot to the cold spot is basically present. The H-H-type areas are mainly distributed in the eastern coastal areas, the H-L-type areas are mainly the capital cities and economic centers in the central and western regions, the L-H type includes four cities: Chuzhou, Qingyuan, Shanwei and Jieyang, and the L-L-type areas are mainly distributed in the northwest and northeast regions.

The 10 influencing factors selected have different positive effects on the construction of ecological civilisation. Among them, the abundance of ecological resources is the most influential factor, and the effects of various indicators all show strong spatial heterogeneity. The construction of ecological civilisation in Northeast China and the central and western regions is affected more by economic operation and adjustment. The central and eastern regions are more susceptible to subjective factors such as policy and cultural awareness.

References

Bebber D, 1999. Spatial autocorrelations. *Trends in Ecology & Evolution*, 14(5): 196. doi:10.1016/s0169-5347(99)01607-9

Brunsdon C, Fotheringham S, Charlton M, 1998. Geographically weighted regression. *Journal of the Royal Statistical Society: Series D* (*The Statistician*), 47(3): 431–443. doi:10.1111/1467-9884.00145

Dryzek J S, Stevenson H, 2011. Global democracy and earth system governance. *Ecological Economics*, 70(11): 1865–1874. doi:10.1016/j.ecolecon.2011.01.021

Fan Jie, Zhou Kan, Sun Wei et al., 2013. Scientific values and research innovations of Human-economic Geography in construction of ecological civilization. *Progress in Geography*, 32(2):147–160. (in Chinese)

Fritz M, Koch M, 2016. Economic development and prosperity patterns around the world: structural challenges for a global steady-state economy. *Global Environmental Change*, 38: 41–48. doi: 10.1016/j.gloenvcha.2016.02.007

Getis A, Ord J K, 2008. The analysis of spatial association by use of distance statistics. *Advances in Spatial Science*, 127–145. doi:10.1007/978-3-642-01976-0_10

Gu ShuZhong, Hu YongJun, Zhou Hong, 2013. Ecological civilization construction: scientific connotation and basic paths. *Resources Science*, 35(1): 2–13. (in Chinese)

Hansen M H, Li H, Svarverud R, 2018. Ecological civilization: interpreting the Chinese past, projecting the global future. *Global Environmental Change*, 53: 195–203. doi:10.1016/j.gloenvcha.2018.09.014

He Tianxiang, Liao Jie, Wei Xiao, 2011. Construction of indictors system for evaluation of urban ecological civilization. *Economic Geography*, 31(11): 1897–1900, 1879. (in Chinese)

Li Wei, Xi Yongqin, 2016. Research on provincial ecological civilization construction evaluation under the efficiency perspective. *Acta Ecologica Sinica*, 36(22): 7354–7363. (in Chinese)

Liao Yuwen, Zhang Yanni, 2011. Eco-civilization's connotation and practical significance. *China Population*, *Resources and Environment*, 21(S1): 377–380. (in Chinese)

Liu H, Liu Y, Wang H et al. 2019. Research on the coordinated development of greenization and urbanization based on system dynamics and data envelopment analysis: a case study of Tianjin. *Journal of Cleaner Production*, 214: 195–208 doi:10.1016/j.jclepro.2018.12.046

Ma Daoming, 2009. Study on the construction path and evaluation eystem of eco-civilized city. *Urban Studies*, 16(10): 80–85. (in Chinese)

Mi Zefeng, Zhou Can, Zhu Feifei et al., 2018. The path dependence and relationship change of ecological civilization construction: Based on the panel data analysis of prefecture-level cities in the Yangtze River Economic Belt from 2003 to 2015. *Geographical Research*, 37(10): 1915–1926. (in Chinese)

MWRC (Ministry of Water Resources of the People's Republic of China), 2018. *China Water Resources Bulletin*. Beijing: China Water Power Press. (in Chinese)

NBSC (National Bureau of Statistics of China), 2018. *China Statistical Yearbook for Regional Economy*. Beijing: China Statistics Press. (in Chinese)

NBSC (National Bureau of Statistics of China), 2018. *China City Statistical Yearbook*. Beijing: China Statistics Press. (in Chinese)

Pelletier N, 2010. Of laws and limits: an ecological economic perspective on redressing the failure of contemporary global environmental governance. *Global Environmental Change*, 20(2): 220–228. doi: 10.1016/j.gloenvcha.2009.12.006

Qin Weishan, Zhang Yifeng, Yuan Jing, 2013. Measuring and Defining Eco-civilization Cities in China. *Resources Science*, 35(8): 1677–1684. (in Chinese)

Schneider F, Kallis G, Martinez-Alier J, 2010. Crisis or opportunity? Economic degrowth for social equity and ecological sustainability. Introduction to this special issue. *Journal of Cleaner Production*, 18(6): 511–518. doi:10.1016/j.jclepro.2010.01.014

Söderbaum P, 2015. Varieties of ecological economics: do we need a more open and radical version of ecological economics? *Ecological Economics*, 119: 420–423. doi:10.1016/j.ecolecon.2015.09.007

Wang Geng, Li Sujuan, Ma Qifei, 2018. Spatial equilibrium and pattern evolution of ecological civilization construction efficiency in China. *Acta Geographica Sinica*, 73(11): 2198–

2209. (in Chinese)

Wang X, Chen X, 2019. An evaluation index system of China's development level of ecological civilization. *Sustainability*, 11(8): 2270. doi:10.3390/su11082270

Wold S, Esbensen K, Geladi P, 1987. Principal component analysis. *Chemometrics and Intelligent Laboratory Systems,* 2(1–3): 37–52. doi:10.1016/0169-7439(87)80084-9

Xiang Jingyi, Zhang Hongju, Chen Li et al., 2018. Conceptualization and evaluation indicators of aquatic ecological civilization based on content analysis. *China Population*, *Resources and Environment*, 28(S1): 169–175. (in Chinese)

Xiao L, Zhao R, 2017. China's new era of ecological civilization. *Science*, 358(6366): 1008–1009. doi:10.1126/science.aar3760

Xin Y, 2019. Problems and countermeasures of urban ecological civilization construction in China. *Environmental Technology,* 10(1): 1–10. doi:10.4236/lce.2019.101001

Yu Shengwen, Li Linjun, Qiu Guoyu, 2015. Evaluation of the eco-civilization construction of Shenzhen based on catastrophe progression method. *Ecological Economy*, 31(12): 174–181, 195. (in Chinese)

Zhang C, Quan Y, Zhong H, 2019. The building of marine ecological civilization and sustainable development: conference report. *Marine Policy*, 110: 103627. doi:10.1016/j.marpol.2019.103627

Zhang H, Cheng J H, Feng Y et al., 2015. An evaluation index system for ecological civilization construction in megacities and its research applications: the case of Wuhan City. *Acta Ecologica Sinica*, 35(2): 547–556. doi: 10.5846/stxb201303220493

Zhang Hao, Sun Jian, Deng Wei et al., 2020. Ecosystem health: assessment framework, spatial evolution, and regional optimization in southwest China. *Chinese Geographical Science*, 30(1): 142–156. doi:10.1007/s11769-020-1101-8

Zhang L, Zhang D Y, 2011. Relationship between ecological civilization and balanced population development in China. *Energy Procedia*, 5: 2532–2535. doi:10.1016/j.egypro.2011.03.435

Zhang Peng, Li Ping, Li Wenhui, 2017. Research on the construction of eco-civilized cities based on moderate population capacity: a case study of Huizhou City, Guangdong Province. *China Population*, *Resources and Environment*, 27(8): 159–166. (in Chinese)

Zhang X, Wang Y, Qi Y et al., 2016. Evaluating the trends of China's ecological civilization construction using a novel indicator system. *Journal of Cleaner Production*, 133: 910–923. doi:10.1016/j.jclepro.2016.06.034

Zhang Zhiguang, 2019. Development ideology in the new era: the ideology of ecological civilization from the viewsheds of China and mankind progress. *China Population, Resources and Environment*, 29(2): 7–15. (in Chinese)

Zhu Z Y, Li B, Gao M et al., 2010. Preliminary research on quantitative indicators for ecological civilization city construction of taihu lake basin. *Engineering Sciences*, 12(6): 131–136.doi: 10.3724/SP.J.1088.2010.00432