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Research Article

Evaluation of Ecological Environment Quality in Chongqing Main City Area Based on Principal Component Analysis

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With the rapid development of social productive forces in China, the process of urbanization has been accelerating, resulting in the deterioration of urban environmental quality and the destruction of ecosystems, such as debris flow, drought, water bloom, large-scale haze weather, and other ecological and environmental problems. The quality of the urban ecological environment is not only related to the stability of urban ecological function but also affects the sustainable development of the city. Many scholars have studied the problem of ecoenvironmental quality assessment, but there are still some shortcomings in the evaluation process, such as the construction of the index system and the application of related methods. Taking Chongqing as the research object, after referring to the representative evaluation index system in China, the evaluation index system of ecological environment quality in Chongqing was constructed from three aspects of nature, economy, and society. In this article, the principal component analysis (PCA) method is used to construct the ecoenvironmental quality evaluation system of Chongqing, and the economic development, pollutant control, natural protection and pollution reduction investment, urban and rural cooperation, land area, and other aspects are comprehensively evaluated. The relationship between simulated variables and the regression equation was also assessed. Through the comparative analysis of the two evaluation methods, it can be seen that the evaluation results of the PCA method and the fuzzy comprehensive evaluation method are basically the same in the longitudinal trend, which shows that the application of this method in the field of ecological environment quality evaluation has certain scientific rationality.

1. Introduction

Ecological harmony and sustainable development play an increasingly important role in the history of human development. As the gathering point of human development, the quality of the ecological environment is related to the stability of the ecological system and the long-term development of cities. However, due to the emergence of new cities and the continuous expansion of old cities, there have been a series of ecological and environmental problems such as explosive growth of urban population, traffic congestion, urban overload, shortage of water resources, and overall fragility of the urban ecosystem. Under the cross-influence of the contradiction between environmental protection and economic development, the importance of sustainable development has become increasingly prominent. The construction and protection of the ecological environment and corresponding academic research are the basis of making urban environmental planning and urban economic and social development planning. The construction and protection of the ecological environment have important guiding significance.

Some scholars have studied the ecological evaluation system and discussed the ecological environment level of Chongqing and concluded that there is a strong correlation between the fluctuation of urban ecological environment quality and the investment level of ecological level [1]. Some researchers use time series analysis (PCA) to evaluate the environmental quality of Chongqing. It can be seen that the rural subsystem and the urban subsystem are opposite, and there is a negative evolution problem [2]. Some researchers have analyzed the evolution law and driving factors of urbanization quality in Chongqing by entropy method, factor contribution rate, and contribution elasticity analysis and found that ecological environment and urban-rural coordinated development quality are the "main engines" for improvement [3]. Using quantitative methods of landscape ecology and RS-GIS techniques [4], some researchers explored the contradictions among human activities, urban enrollment expansion, and natural ecological landscape development in Chongqing. Some researchers combined GIS and AHP methods, combined with the regional environmental characteristics of western Chongqing, constructed the ecological environment evaluation index system in western Chongqing, and studied the correlation between ecological environment and social, economic, and environmental pollution factors [5]. Some researchers use RS and GIS technology to evaluate the ecological environment quality of the Three Gorges Reservoir [6]. It is concluded that the horizontal distribution of ecological environment quality is closely related to the vertical difference of slope and the regional difference in reservoir area. Some researchers have studied the environmental problems in the Qianjiang area of Chongqing and given corresponding schemes and measures, which are beneficial to the sustainable development of the Qianjiang area [7]. Some scholars have constructed the hierarchical structure of ecological data indicators and the dynamic monitoring and early warning system of ecological quality in Chongqing [8], which provides theoretical support for improving the efficiency of the urban ecological environment and the early warning level of ecological security in Chongqing. Based on the coordination degree model, some researchers discussed the urbanization level and regional differences in the Chengdu-Chongqing area [9] and concluded that economy, population, and infrastructure levels are the main driving factors affecting the spatial differences in urbanization quality in the Chengdu-Chongqing area. Some researchers investigated the factors of water stress and the effectiveness of water management measures in Chongqing. The research shows that the improvement of the water resources system is mainly due to the increase in forest coverage rate and the continuous investment in the ecological management of the Three Gorges Reservoir [10]. Some researchers have completed the calculation and analysis of ecological footprint in Chongqing from 2000 to 2013, and the results reflect the stress trend of ecological environment sustainable development ability and ecological capacity in the study area. According to the ecological security situation of land resources in Chongqing [11], some researchers put forward some suggestions on coordinating land resources, strengthening land management, and ecological environment protection [12]. Based on the theory of regional division of labor, some researchers have analyzed the driving mechanism of urbanization in Chongqing and put forward the strategic policy of sustainable urbanization [13]. Among some researchers, after investigating the Nan'an District of Chongqing, it is concluded that the increase in the proportion of the nonagricultural population and economic development are important factors affecting the ecological environment index [14]. Overexploitation of land and other factors have a negative impact on natural ecology. Some researchers have studied the dynamic changes in land use and landscape pattern in the Chongqing metropolitan area in the past 20 years and concluded that the management and decision-making departments should formulate scientific and reasonable land use planning and urban development planning and strengthen ecological environment protection while developing economy [15]. In the introduction to describe the relevant literature, in the current study, it can be seen that different regions, using different methods have different effects. According to different regions and different time periods in Chongqing, the method is analyzed and applied, and it has been widely used. In different applications, due to the differences in methods, the analysis results are also different. The PCA model can be used to analyze the correlation degree of different index parameters in depth.

Section 2 of the article explains some concepts and concepts of ecological environment quality assessment in the main urban area of Chongqing. Section 3 establishes the evaluation index system of ecological environment quality in Chongqing. Section 4 demonstrates the ecological environment quality evaluation by PCA in Chongqing.

2. Related Theories of Ecological Environment Quality Evaluation in the Main Urban Area of Chongqing

2.1. Urban Ecosystems. A city is the product of coordinated survival and development of human beings, which has the characteristics of sufficient population, and the trinity of culture, economy and science, and technology. The urban ecosystem refers to the combination of the urban environment and organic life within the city, which is mainly formed by the human transformation of the natural ecosystem. The urban ecological environment includes natural ecological environment, social environment, economic environment, and artificial ecological environment. Various environmental components interact and restrict each other through material exchange, energy circulation, information circulation, and other functions, forming an organic unity. Through the evaluation of nature, culture, and economy, we can quantitatively understand the ecological environment quality of the evaluated city and further explore the concrete planning of urban sustainable development and understand the specific situation of specific urban areas.

At present, most of the mainstream views focus on long-term development, and scholars also use this view to evaluate the quality of the ecological environment. For example, the Environmental Sustainable Development Index (ESI) jointly constructed by Yale University, Columbia University, and the World Economic Forum in 2000 is predictable abroad and is an important reference for evaluating the environmentally sustainable development of all countries in the world. Similarly, the Human Development Index proposed by the United Nations Development Programme and the developmental financial dividend model created by the Canadian Institute for Sustainable Development. In the 1980s, China's ecological environment just began to appear. In 2000, Ye and Liu [16] established an ecological environment evaluation system based on the current situation and causes of the ecological environment. In 2002, Yongming [17] established an ecological environment evaluation index system in Mizhi County, Shaanxi Province, based on the restrictive factors of ecological environment quality. At the same time, the task of quantitative evaluation and analysis of ecological environment quality in the whole county was completed.

2.2. Regional Overview of the Main Urban Area of Chongqing. The main urban area of Chongqing, also known as the urban developed economic circle, is located in the central and western part of Chongqing, and its geographical area, resident population, and rural area are similar to those of the provincial capital city of a medium-sized province. The main urban area of Chongqing includes nine administrative districts, including Yuzhong District, Dadukou District, Jiangbei District, Shapingba District, Jiulongpo District, Nan'an District, Beixian County, Yubei District, and Banan District, covering an area of 5,473 square kilometers. At the end of 2011, the total population was about 6,228,500, and the resident population was 7,723,100, forming 21 large-scale settlements.

The main urban area of Chongqing is the political, economic, cultural, financial, and industrial center of the whole city, belonging to the core area of the "one-hour economic circle" and the key development zone of the main functional area. In the area accounting for 7% of the whole city, 24.7% of the population of the whole city lives, creating about 43.6% of the GDP of the whole city.

3. Establishment of Ecological Environment Quality Evaluation Index System in Chongqing

3.1. Selection and Composition of Index System. This article takes the natural environment quality and ecological quality as the main evaluation objects and considers the close relationship between urban natural environment quality and economy, humanities, and society, so as to improve the level of urban development, pollution control, and resource utilization, including 12 evaluation indicators, 9 ecological quality evaluation indicators and 8 urban development level, pollution control, and resource utilization level indicators, totaling 37 evaluation indicators. Among them, according to the special physical and geographical characteristics of the main urban area of Chongqing and the development characteristics of cluster urbanization, the indicators such as water surface coverage, water network density, heat island intensity, landscape diversity index, landscape fragmentation index, biological abundance index, and vegetation coverage index are selected in Table 1.

3.2. Evaluation Method and Calculation Model. Many methods can be used to evaluate the quality of the ecological environment, but due to the influence of guiding ideology and objective conditions, the choice of specific schemes varies from person to person. In this article, from the perspective of eliminating the restriction of subjective factors to the maximum extent, On the basis of the subjective scoring method of experts, combined with advanced technologies such as geographic information system and remote sensing to obtain relevant geospatial data information, AHP analytic hierarchy process is adopted to calculate the weight of the set indicators, and reasonable evaluation standard values are set to comprehensively evaluate and analyze the ecological environment quality of the study area.

AHP is a qualitative and quantitative decision analysis method by American operational research scientist T.L.Carl in the 1970s. It is often used in multiobjective, multistandard, multifactor, multilevel unstructured, and complex decision-making problems. The analysis of elements and their internal relations is thorough. At the same time, AHP decision analysis has some subjectivity. In the actual analysis, in order to eliminate the inaccurate factors caused by subjectivity, this article has conducted a large number of consultations with experts in this field and synthesized the different opinions of various experts so that the index weight obtained is objective and fair to the maximum.

3.3. Determination of Evaluation Weight.

(1) When determining the weight of each index, the first step is to construct a judgment matrix B for each index of the same level (see Table 2).

In the matrix, Bn is the destination layer of *Ak*, and b_{ij} represents the mathematical degree of mutual importance among elements *Bi*, *Bj*, and *Ak*. Bij uses five scales 1, 3, 5, 7, and 9 in the matrix; namely, 1 means that *Bi* and Bj are at the same level; 3 means that *Bi* is a little more important than *Bj*; 5 means that *Bi* is much more important than *Bj*; 7 means *Bi* is more important than *j*; 9 indicates that *Bi* is extremely important than *Bj*. In practical application, 2, 4, 6, and 8 can be selected to characterize the relative importance of *Bi* and *Bj*.

Obviously, for any judgment matrix, it should satisfy the following:

$$b_{ij} = \frac{1}{b_{ji}} \quad (i, j = 1, 2, \ldots, n), \tag{1}$$

n in the above formula belongs to N.

(2) Hierarchical single sorting: single sorting can be used to obtain the weight ratio of importance between adjacent elements. It is the basis for ordering the importance of all elements in this layer to the previous layer. The task of hierarchical single ranking can be reduced to the problem of calculating the eigenvalues and eigenvectors of the judgment matrix, that is, for the judgment matrix B, calculate the eigenvalues and eigenvectors of the following formula:

$$BW = \lambda_{\max} W. \tag{2}$$

Table 1: Index composition of evaluation system.

Criterion layer	Indicator layer
City size	Built-up area, specific population density, per capita construction land, economic density, expansion intensity of built-up area, greening of built-up area, population density, per capita road area, specific coverage rate of water area, etc.
Natural environment quality	Water surface coverage rate, water network density, per capita water area, excellent air quality ratio, acid rain frequency, heat island intensity, water quality comprehensive pollution index, water nutrition status index, water quality compliance rate in water functional areas, water quality compliance rate in centralized drinking water sources, regional environmental noise, and traffic trunk noise
Ecological quality factors	Ecological land use ratio, landscape diversity index, landscape fragmentation index, land degradation index, soil environmental quality comprehensive index, endangered species index, biological invasion risk, biological abundance index, and vegetation coverage index
Pollution control and energy coordination capabilities	Safe disposal rate of hazardous waste, harmless treatment rate of garbage, comprehensive disposal utilization rate of industrial solid waste, clean energy utilization rate, water resources carrying capacity, water consumption per unit GDP, urban sewage treatment rate, and added value of energy consumption per unit above designated size

Table 2: Hierarchical judgment matrix.

A_k	B_1	B_2	$\cdots$	B_n
B_1	b_{11}	b_{12}	$\cdots$	b_{1n}
B_2	b_{21}		$\cdots$	
$\vdots$	$\vdots$	$\vdots$	$\cdots$	$\vdots$
B_n	b_{n1}	b_{n2}	$\cdots$	b_{nn}

In the above formula, $\lambda_{\max}$ is the largest eigenroot of B, W is the normalized eigenvector corresponding to $\lambda_{\max}$, and the component Wi of W is the weight value of single-order corresponding elements.

When there is $b_{ij} = b_{ik}/b_{jk} \quad (i, j, k = 1, 2, \ldots, n)$ in the judgment matrix B, then the judgment matrix B is completely consistent, $\lambda_{\max} = n$. However, it is impossible under normal circumstances. Therefore, it is necessary to calculate the consistency of the matrix:

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1}. \tag{3}$$

In the formula, when CI = 0 and n belongs to N, the judgment matrix is completely consistent; on the contrary, the larger the CI, the worse the consistency of the judgment matrix.

In order to test whether the judgment matrix has satisfactory consistency, it is necessary to compare CI with the average random consistency index RI (see Table 3).

Generally speaking, the first-order or second-order judgment matrix is always the same. For judgment matrices above grade 2, the ratio of consistency index CI to equivalent average random consistency index RI is called the random consistency ratio of judgment matrix, which is recorded as CR. Generally speaking, when CR < 0.10, we think that the judgment matrix has satisfactory consistency; that is, the relative importance of the assigned indicators is desirable.

The calculation method of CR is shown in the following formula:

$$CR = \frac{CI}{RI}. \tag{4}$$

(3) Hierarchical total sorting: using a single sorting result of all levels in the same level, you can calculate the weight value of all elements in that level to the previous level, which is called total level sorting. Hierarchical total sorting needs to be done hierarchically from top to bottom. For the highest level, its hierarchical single sorting is its total sorting.

If the total hierarchical ordering of all elements $A1$, $A2$, . . ., Am in the previous hierarchy has been completed, the obtained weight values are $A1$, $A2$, . . ., respectively, and the hierarchical single ordering result of the current hierarchical elements $B1$, $B2$, . . ., Bn corresponding to AJ is $[b_1^j, b_1^j, \ldots, b_n^j]$ (here, when Bi is irrelevant, Ai, $b_1^j = 0$). See Table 4 for the overall ranking of levels.

Obviously,

$$\sum_{i=1}^{n} \sum\nolimits_{j-1}^{m} a_j b_n^j = 1. \tag{5}$$

That is, the total ranking of levels is normalized normal vectors. n in the above formula belongs to N.

(4) Consistency test: after the ranking list is sorted, it is necessary to count CI, RI, CR, etc. and complete the consistency check of the calculation results of the total ranking.

$$CI = \sum_{j=1}^{m} a_j CI_j,$$
$$RI = \sum_{j=1}^{m} a_j RI_j, \tag{6}$$
$$CR = \frac{CI}{RI}.$$

Among the above three types, CI is the consistency index of the total ranking; CIj is the consistency index

Table 3: Average random consistency index.

Order	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.90	0.12	1.24	1.32	1.41	1.45	1.49	1.52	1.54	1.56	1.58	1.59

Table 4: Hierarchical total sorting table.

Hierarchy B	A_1 A_2 … A_m a_1 a_2 … a_m	B-level total sorting
B_1	b_1^1 b_1^2 … b_1^m	
B_2	b_2^1 b_2^2 … b_1^m	$\sum_{j-1}^{m} a_j b_n^j$
⋮	⋮ ⋮ ⋮	
B_n	b_n^1 b_n^2 … b_n^m	

of the *B*-level judgment matrix corresponding to *aj*; *RI* is the random consistency index of total ranking; *RIj* is the random consistency index of *B*-level judgment matrix corresponding to *aj*; *CR* is the random consistency ratio of the total ranking of hierarchies.

Similarly, when CR is 0.10, it is considered that the calculation results of the hierarchical total ranking are relatively consistent, and the relative importance judgment matrix can be accepted; otherwise, the judgment matrix needs to be adjusted to make the overall hierarchy more consistent.

(5) Calculation of data: according to the constructed judgment matrix, the following calculations are made:

Step 1: Judge the product of matrix elements:

$$M_i = \prod_{j=1}^{n} b_{ij} \lim_{x\longrightarrow\infty} \quad (i = 1, 2, \ldots, n), \tag{7}$$

n in the above formula belongs to N.

Step 2: Calculate M_i to the nth power:

$$\overline{W_i} = \sqrt[n]{M_i} \quad (i = 1, 2, \ldots, n). \tag{8}$$

Step 3: Normalization of eigenvectors:

$$W_i = \frac{\overline{W_i}}{\sum_{i=1}^{n} W_i} \quad (i = 1, 2, \ldots, n). \tag{9}$$

Step 4: Maximum characteristic root:

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(BW)_i}{nW_i}. \tag{10}$$

In the above formula, $(BW)_i$ represents the i-th component of the vector BW.

Through the above-mentioned four-step calculation, a random consistency test can be carried out to know whether the constructed judgment matrix is satisfactory or not.

4. Evaluation of Ecological Environment Quality by Principal Component Analysis in Chongqing

4.1. Construct Principal Component Evaluation Model.

Step 1: The original data are processed in the same direction and standardized.

Step 2: Check the applicability of the original data and determine the correlation between the index data.

Step 3: Calculate the correlation coefficient matrix R:

$$R = \left(\rho_{ij}\right)_{p\times p} = \begin{bmatrix} \rho_{11} & \rho_{11} & \cdots & \rho_{1p} \\ \rho_{21} & \rho_{22} & \cdots & \rho_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ \rho_{p1} & \rho_{p2} & \cdots & \rho_{pp} \end{bmatrix}, \tag{11}$$

ρ_{ij} is the correlation coefficient between variables x_i and x_j, $\rho_{ij} = \rho_{ji}$ (i, $j = 1, 2, 3, \ldots, p$), which can be calculated as follows:

$$\rho_{ij} = \frac{1}{n} \times \frac{\sum_{k=1}^{n}\left(x_{ij} - \overline{x_i}\right)\left(x_{kj} - \overline{x_j}\right)}{S_i S_j}. \tag{12}$$

Step 4: Calculate the eigenvalue λ_i of the correlation coefficient matrix R and the corresponding unit eigenvector $\overline{a_i}$ and determine the principal component:

$$N_i = a_{i1}z_1 + a_{i2}z_2 + \cdots + a_{ip}z_p, \quad i = 1, 2, 3, \ldots p. \tag{13}$$

The relationship between the factor load coefficient u_{ij} and the eigenvalue λ_i is used to obtain the eigenvector $\overline{a_i}$, and then the principal component is obtained:

$$a_{ij} = \frac{u_{ij}}{\sqrt{\lambda_i}} \quad (i = 1, 2, 3, \ldots m; j = 1, 2, 3, \ldots p). \tag{14}$$

Step 5: Calculate the variance contribution rate and cumulative contribution rate and determine the principal component score.

Calculation formula of variance contribution rate:

$$F_1 = \frac{\lambda_i}{\sum_{i=1}^{p} \lambda_i}. \tag{15}$$

Calculation formula of cumulative contribution rate:

$$F_2 = \sum_{i=1}^{m} \left(\frac{\lambda_i}{\sum_{i=1}^{p} \lambda_i}\right). \tag{16}$$

In the usual definition, when the cumulative contribution rate is greater than 85%, it can be considered that the selected new principal component can complete the replacement of the original variable and can also summarize most of the information of the original variable. Here, we take m principal components that satisfy the conditions.

4.2. Indicator Data Preprocessing. Before the PCA, we need to normalize the original index data so as to compare and analyze the indexes in the same evaluation index system. The evaluation index attributes involved in this article are divided into two categories: positive index, that is, the higher the index value, the better the ecological environment quality; negative index, that is, the lower the index value, the better the ecological environment quality. Before normalizing the dimension, it is necessary to convert the negative index into the positive index, and the usual method is to take the reciprocal of the original value. At present, the most commonly used dimension normalization method is the standard deviation normalization method, which is calculated according to the following formula:

$$zx_{ij} = \frac{x_{ij} - \overline{x_j}}{S_j}, \tag{17}$$

where $\overline{x_j} = 1/n \sum_{i=1}^{n} x_{ij}$; x_{ij} is the original value of j index; $\overline{x_j}$ and S_j are the sample mean and standard deviation of j index, respectively; N is the number of samples.

According to the above steps, combined with the software SPSS19.0, the data of Chongqing ecological environment quality evaluation index are normalized in dimensions, and the results are shown in Table 5 and Figure 1.

4.3. Calculation of Ecological Environment Index.

(1) Applicability test of component analysis

It can be seen from Table 6 that the KMO value is 0.748, which is greater than 0.5, indicating that this set of index data can be used for PCA. The adjoint probability of the Bartlett ball test is 0.000, which is less than the significance level of 0.05. The original hypothesis of Bartlett's sphericity test is rejected, so it is considered to be suitable for PCA.

(2) The correlation degree between indexes is preliminarily determined by the correlation coefficient matrix R. The results are shown in Table 7.

(3) Calculate the eigenvalue input, variance contribution rate, and cumulative contribution rate of correlation coefficient matrix R, and determine the number of principal components.

It can be seen from Table 8 that the cumulative contribution rate of the first principal component $N1$, the second principal component $N2$, and the third principal component $N3$ is 88.400%, which is more than 85%, indicating that these three principal components can reflect the natural ecological environment indicators. Most of the information provided. Therefore, the first principal component $N1$, the second principal component $N2$, and the third principal component $N3$ are used to evaluate the natural ecological environment quality of Chongqing.

(4) Calculate the feature vector corresponding to the selected principal component and write out the principal component expression in Table 9.

The principal component load represents the correlation coefficient between each index and a principal component. Feature vectors represent the weights of each index in different principal components. The principal component expression is as follows:

$$\begin{aligned}
N_1 &= \left(\frac{0.114Z_{x1} - 0.983Z_{x2} + 0.896Z_{x3} + 0.871Z_{x4} + 0.860Z_{x5} + 0.699Z_{x6} + 0.571Z_{x7} + 0.866Z_{x8} + 0.931Z_{x9}}{\sqrt{5.711}}\right),\\
N_2 &= \left(\frac{0.759Z_{x1} + 0.021Z_{x2} - 0.304Z_{x3} - 0.380Z_{x4} + 0.252Z_{x5} + 0.498Z_{x6} + 0.318Z_{x7} - 0.143Z_{x8} - 0.091Z_{x9}}{\sqrt{1.255}}\right),\\
N_3 &= \left(\frac{0.470Z_{x1} + 0.010Z_{x2} - 0.010Z_{x3} - 0.026Z_{x4} - 0.130Z_{x5} - 0.054Z_{x6} - 0.728Z_{x7} + 0.418Z_{x8} - 0.206Z_{x9}}{\sqrt{0.990}}\right).
\end{aligned} \tag{18}$$

4.4. Trend Chart of Evaluation Results. In order to reflect the change trend of the ecological environment in Chongqing more intuitively, the change trend chart of the ecological environment index and the change trend chart of principal components of the ecological environment system in Chongqing from 2009 to 2019 were obtained, as shown in Figures 2 and 3.

4.5. Analysis of Trend Chart Results. According to the principal component model, the comprehensive scores of each grade are positive and negative. In fact, the values here do not represent the true meaning of each index. It shows the relative position of the ecological environment quality in a certain year in all years, that is, the positional relationship between the ecological environment quality in a certain year and the average level in recent years. Taking the average level of ecological environment quality in Chongqing as the zero point, the farther away it is from the zero point, the better the corresponding ecological environment quality is; the farther the negative value is from zero, the worse the corresponding ecological environment quality is.

It can be seen from Figure 1 that if only the natural environment index is considered, the ecological environment index in 2018 is less than 0, lower than the average level, and its index value is greater than that in 2018, indicating that in terms of ecological environment quality, 2018 is better than 2019. On this basis, considering economic and social factors comprehensively, the index value obtained by analysis is lower than that in 2019, and its absolute value is

Table 5: Standardization of raw data.

Year	*zx*1	*zx*2	*zx*3	*zx*4	*zx*5	*zx*6	*zx*7	*zx*8	*zx*9
2009	−0.339	1.407	−0.771	−0.865	−2.579	−1.028	−1.17	−0.645	−1.143
2010	−0.962	1.407	−0.816	−0.663	−0.832	−2.592	−2.084	−1.385	−1.382
2011	−0.861	0.749	−0.732	−0.793	−0.333	0.184	−0.696	−1.196	−0.545
2012	2.434	0.419	−0.642	−0.728	0.083	0.151	0.646	−0.803	−0.874
2013	−0.993	0.09	−0.612	−0.727	0.067	0.712	0.726	−0.677	−0.844
2014	0.653	0.09	−0.411	−0.397	0.271	0.164	0.228	−0.299	0.143
2015	0.515	−0.24	−0.313	−0.335	0.279	0.066	−0.632	0.85	0.203
2016	0.399	−0.24	−0.002	0.054	0.598	1.011	−0.757	1.023	1.025
2017	−0.647	−0.569	0.777	1.087	0.679	0.516	0.776	1.023	1.13
2018	−0.201	−1.557	1.352	1.72	0.851	0.457	0.786	1.023	1.13
2019	0.004	−1.557	2.172	1.647	0.916	0.36	0.786	1.086	1.16

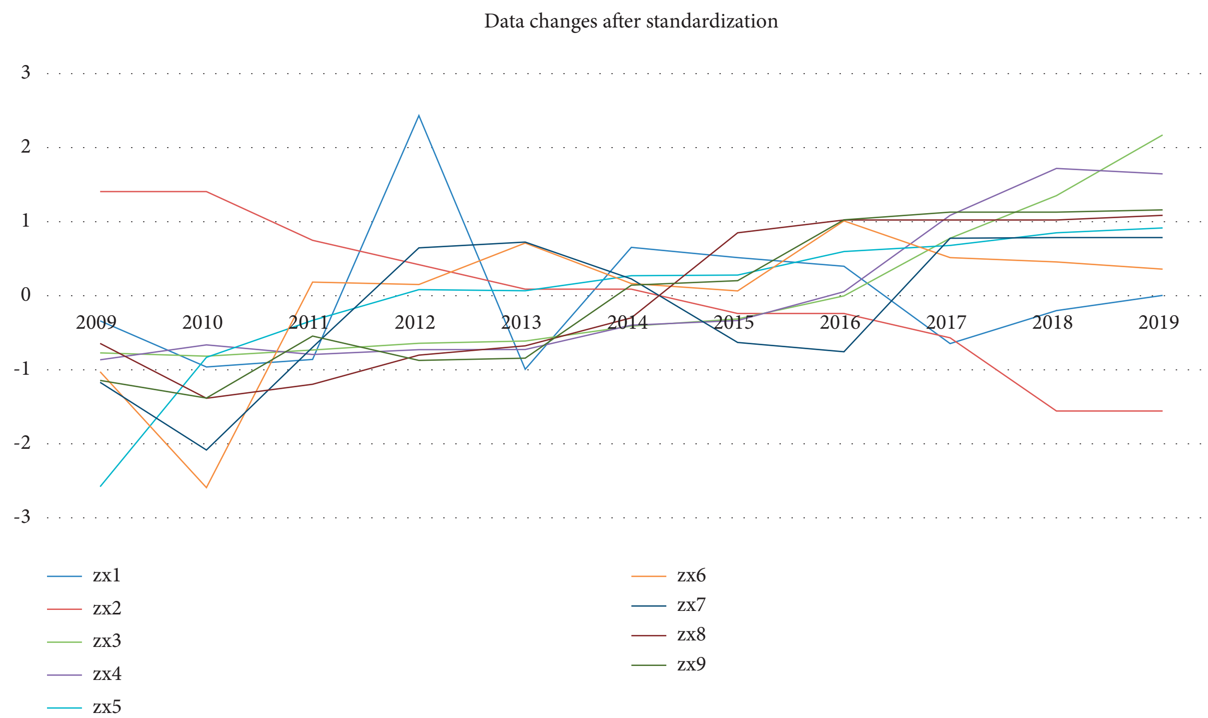

Figure 1: Standardized data change chart.

Table 6: Test results of KMO and Bartlett.

Kaiser–Meyer–Olkin measure	0.748	
Bartlett sphericity test	Approximate chi-square	87.767
	Df	36.00
	Sig	0.00

Table 7: Correlation coefficient matrix of natural ecological environment index.

Indicators	*X*1	*X*2	*X*3	*X*4	*X*5	*X*6	*X*7	*X*8	*X*9
*X*1	1	−0.103	−0.016	−0.072	0.205	0.247	0.031	0.109	0.055
*X*2	−0.103	1	−0.89	−0.869	−0.833	−0.664	−0.563	−0.849	−0.889
*X*3	−0.016	−0.89	1	0.984	0.642	0.401	0.459	0.761	0.795
*X*4	−0.072	−0.869	0.984	1	0.636	0.307	0.436	0.739	0.779
*X*5	0.205	−0.833	0.642	0.636	1	0.654	0.624	0.643	0.765
*X*6	0.247	−0.664	0.401	0.307	0.654	1	0.536	0.586	0.652
*X*7	0.031	−0.563	0.459	0.436	0.624	0.536	1	0.132	0.338
*X*8	0.109	−0.849	0.761	0.739	0.643	0.586	0.132	1	0.933
*X*9	0.055	−0.889	0.795	0.779	0.765	0.652	0.338	0.933	1

Table 8: Eigenvalue and contribution rate table of ecological environment indicators.

Composition	Eigenvalue	Contribution rate of variance	Cumulative contribution rate
*N*1	5.711	63.459	63.459
*N*2	1.255	13.945	77.404
*N*3	0.99	10.996	88.4
*N*4	0.631	7.017	95.417
*N*5	0.257	2.852	98.269
*N*6	0.075	0.832	99.102
*N*7	0.053	0.593	99.694
*N*8	0.021	0.228	99.922
*N*9	0.007	0.078	100

Table 9: Principal component index table of ecological environment.

Indicators	Principal component		
	*N*1	*N*2	*N*3
*X*1	0.114	0.759	0.47
*X*2	−0.983	0.021	0.01
*X*3	0.896	−0.304	−0.01
*X*4	0.871	−0.38	−0.026
*X*5	0.86	0.252	−0.13
*X*6	0.699	0.498	−0.054
*X*7	0.571	0.318	−0.728
*X*8	0.866	−0.143	0.418
*X*9	0.931	−0.091	0.206

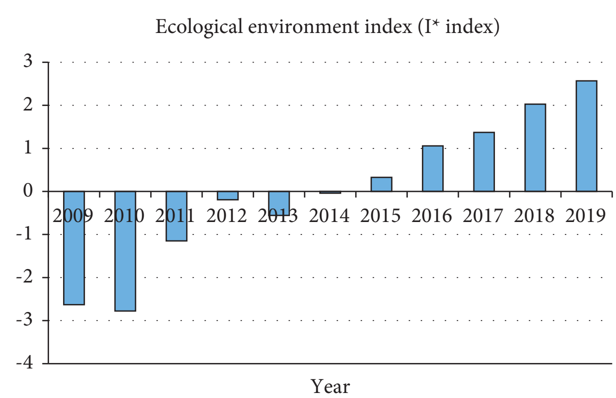

Figure 2: Change trend chart of ecological environment index in Chongqing.

higher than that when only considering natural environment indicators. In other years, after considering economic and social factors, the same situation exists. It can be seen from Figure 2 that the change of the first principal component generally shows an upward trend from 2009 to 2019, which is basically consistent with the change range and trend of the ecological environment index of the natural subsystem, indicating that there is a good correlation between them. Land resource utilization, pollution emission intensity, pollution control, and urban greening construction are the main influencing factors of the natural subsystem. In the initial stage of ecocity construction, the value of the first principal component is less than 0, and there are some problems such as high pollution emission intensity, insufficient pollution control, and imperfect urban greening construction. This shows that economic and social factors have a significant impact on the ecological environment. If only the natural environment indicators are considered, the evaluation results cannot fully reflect the actual ecological environment in the evaluation area. In recent years, Chongqing's GDP, environmental protection investment, and public awareness of environmental protection have been improved. Only by paying equal attention to the environment, economy, and society can the sustainable development of the urban ecological environment be better realized.

In this article, the PCA method is used to analyze the ecological environment quality evaluation of the main urban area of Chongqing, and the correlation of indicators is practical in theory, so it is of great guiding significance to study different environmental indicators in the main urban area of Chongqing. In the third and fourth parts of the article, PCA method is used to evaluate the ecological

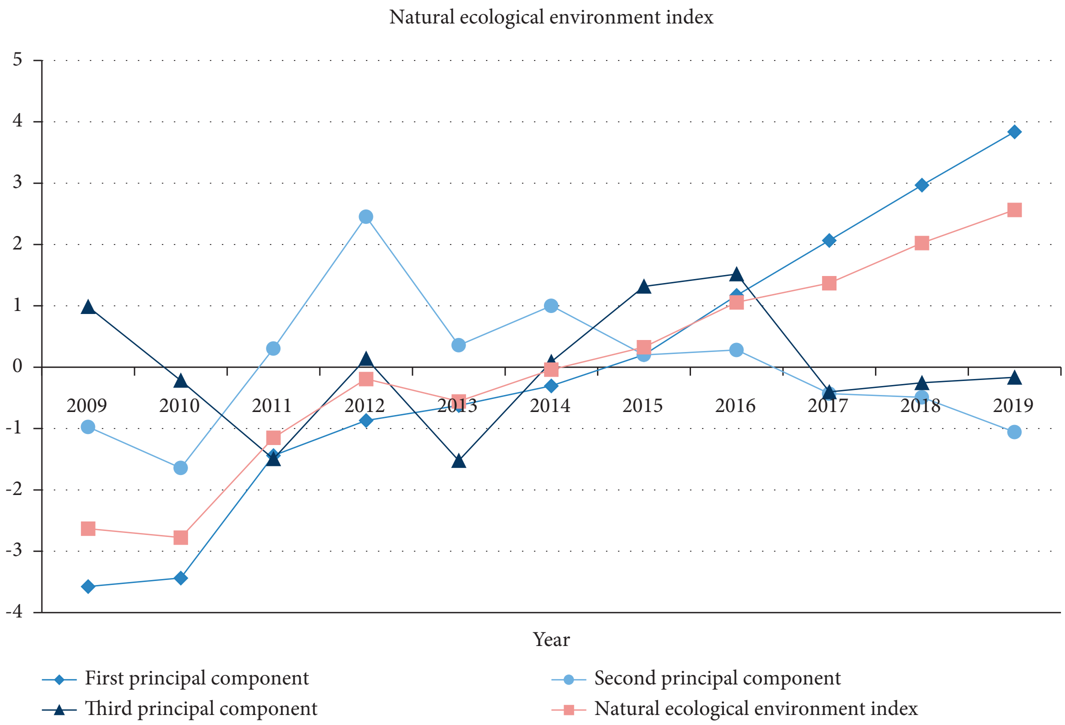

Figure 3: Change trend chart of principal components of ecological environment system in Chongqing.

environment of Chongqing, the data credibility is high, and the example process is rich. Therefore, the research methods in this article have important research significance.

5. Conclusion

When constructing the evaluation index system, if we only consider the selection of natural environment indicators and weaken the economic and social information, it will not fully reflect the quality of the urban ecological environment. According to the understanding of the meaning of urban ecological environment quality in this article, a relatively complete evaluation index system of urban ecological environment quality is constructed from three aspects of nature, economy, and society so as to obtain relatively reasonable evaluation results.

Compared with the fuzzy comprehensive evaluation method and ecological environment index method, the results obtained by the PCA method are basically consistent with them in terms of longitudinal change trend, which shows that the application of this method in urban ecological environment quality evaluation is feasible and the evaluation results are credible. By constructing the ecological environment quality evaluation system and evaluating and analyzing the main urban area of Chongqing in 2019, the results show that the overall score of ecological environment quality evaluation in the main urban area of Chongqing is 82.939 points, ranging from 70 to 85 points, and the ecological environment quality evaluation result is good.

The evaluation results show that from 2009 to 2019, the ecological environment quality of Chongqing is generally on the rise, and it is in a benign development state. The development process can be roughly divided into two stages: 2009~2014 is the initial stage of Chongqing ecocity construction. The index value rises rapidly, but the urban ecological environment quality is generally lower than the average level and is not ideal; from 2009 to 2019, it is the development stage of ecological city construction in Chongqing. The index value keeps increasing continuously, and the ecological environment quality is higher than the average level, developing well. In the future ecological environment construction and protection in Chongqing, we should pay attention to the pollution degree of economic development to the environment, the influence of environmental protection investment on pollution control, and the pressure of population factors on cultivated land resources, further improve environmental protection investment, and improve environmental protection investment construction; adjust the land use structure and relieve the pressure of cultivated land resources; optimize the industrial structure and improve the economic environment.

Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

Acknowledgments

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