Evaluation of Water Resources Carrying Capacity Using Principal Component Analysis: An Empirical Study in Huai’an, Jiangsu, China

Fan Wu ¹, Zhicheng Zhuang ², Hsin-Lung Liu ³,* and Yan-Chyuan Shiau ⁴,*

¹ Business School, Hohai University, Nanjing 211100, China; 191313070041@hhu.edu.cn
² School of Architecture and Design, China University of Mining and Technology, Xuzhou 221000, China; zz_cheng@cumt.edu.cn
³ Department of Leisure Management, Minghsin University of Science and Technology, Hsinchu 30401, Taiwan
⁴ College of Architecture & Design, Chung Hua University, Hsinchu 30012, Taiwan
* Correspondence: hsinlung@must.edu.tw (H.-L.L.); ycshiau@ms22.hinet.net (Y.-C.S.); Tel.: +886-922225586 (H.-L.L.); +886-916047376 (Y.-C.S.)

Abstract: With the rapid development of urbanization, problems such as the tight supply and demand of water resources and the pollution of the water environment have become increasingly prominent, and the pressure on the carrying capacity of water resources has gradually increased. In order to better promote the sustainable development of cities, it is extremely important to coordinate the relationship between water resources and economic society. This study analyzed the current research status of water resources carrying capacity from two aspects, i.e., research perspective and research methodology, established an innovative evaluation system, and used the principal component analysis to analyze the water resources carrying capacity in Huai’an City, an important city in China’s Huaihe River Ecological Economic Zone. Based on the results, it is found that the water resources carrying capacity of Huai’an City has been declining year by year from 2013 to 2019. Based on the evaluation results, suggestions and measures to improve the water resources carrying capacity of the empirical city are proposed to provide an important decision basis for the coordinated development of urban economy, society, and water resources.

Keywords: Huai’an City; water resources carrying capacity; principal component analysis

1. Introduction

Water is an important part of the ecological environment. It has nurtured human civilization and is also an indispensable resource in the development and advancement of agricultural civilization and industrial civilization [1,2]. The concept and connotation of water resources continue to be enriched and improved with the development of human society [3]. Water resources are water sources that have the potential to be used or can be used, which meet the needs of specific uses within a certain time and space, with sufficient quantity and suitable quality [4].

Although water resources are widely distributed and abundant on the earth, with the rapid economic development of China in recent decades, the continuous increase in urban construction land and the continuous accumulation of industries and population have led to a corresponding increase in the demand for water resources. At the same time, due to the lack of environmental awareness and ineffective supervision of water pollution, the problem of water pollution is becoming more and more prominent. How to coordinate the relationship between population, society, economic development and water resources has attracted wide attention from experts and scholars. On the other hand, with the reform of China’s land and space planning, China has focused more and more attention to the environmental capacity and natural resource conditions in the land and space. In order to better implement the construction of ecological civilization and reflect the carrying capacity...
of natural resources of the land and space, the evaluation of the carrying capacity of the resources and environment has become the prerequisite and basis for the compilation of land and space planning [5]. As an important part of the resources and environment, the evaluation of the carrying capacity of water resources is particularly important. Water resources carrying capacity refers to the amount of water resources in the region that can meet the needs of agriculture, industry, the population, and urban development without destroying the ecological and social systems under certain scientific and technological development stages and the social and historical conditions. It is a comprehensive indicator that changes with technology, the economy, and social development.

This study used the existing research results to analyze the data related to water resources in the study area. Based on the results of the analysis, corresponding suggestions were proposed for the rational use of water resources in Huai’an City in the future, which provided an important basis for the management of water resources and the evaluation of the resource and environmental carrying capacity of China’s Huaihe River Eco-economic Zone.

2. Literature Review

The members of the United Nations adopted the 2030 Agenda for Sustainable Development in 2015. It provides an action plan for the prosperity of mankind and the earth. The 17 Sustainable Development Goals (SDGs) and 169 specific goals demonstrate the determination of this agenda. The agenda is based on sustainable development goals. The goal is comprehensive and indivisible. In the context of water governance, two goals are particularly relevant: Goal 6 aims to “ensure availability and sustainable management of water and sanitation for all”; and Goal 17 asserts to “strengthen the means of implementation and revitalize the global partnership for sustainable development” [6]. The integration of different stakeholders in water resources management has always been an important part of sustainable water resources management. However, the complexity of the interaction between people and water is formed by population growth and urbanization, which has changed people’s demand for water resources [7,8]. The assessment of the carrying capacity of water resources has become an important subject of urban development. This section summarizes the theoretical methods of integrated water resources management and analysis as follows.

2.1. Integrated Water Resources Management

At present, many experts and scholars have conducted a lot of research on the carrying capacity of water resources. From the regional perspective, Leiwen et al. discussed the relationship between water resources and population, and pointed out that water resources played an important role in the development of human society [9]. From the perspective of water resources security, the relationship between water resources carrying capacity and water resources safety was investigated, and a water resources safety guarantee system was constructed [10,11]. Rajaram and Das constructed a watershed environmental carrying capacity evaluation model from the perspectives of artificial control of pollution reduction capabilities and ecosystem pollution purification functions. In addition, they took the Dianchi Lake Basin as an example in their calculation and showed that the artificial control of pollution reduction capabilities has gradually become a non-negligible part of improving the water environment carrying capacity of the basin [12]. Kang et al. evaluated agricultural water resources carrying capacity from the perspective of water resources for agricultural development support [13]. Xu and Hu analyzed the relationship between the carrying capacity of water resources and the concept of sustainable development from the perspective of sustainable development. People are paying more and more attention to the social impact brought by changes in the water resources management system. This includes assessing the socio-economic sectors of integrated water resources management, socio-hydrological fields, and the interaction between water systems and humans [14–16]. Konar et al. [17] divided the existing social hydrology research into
four categories: (1) water metabolism, the economic use of water; (2) interaction between humans and drought, (3) interaction between humans and floods; and (4) the role of human institutions, policies, and management. The focus of social hydrology research is the two-way interaction between water and humans [18]. Therefore, only with the support of Integrated water resources management (IWRM), through the interaction between different scientific disciplines and stakeholders, can water-related issues be interconnected and resolved. The study is of great significance for further promoting the coordinated development of economic society and water resources. From the literature discussion, it can be found that water resources management involves a wide range of complex environmental, economic, and social relationships.

2.2. Review of Water Resources Management Theories and Methods

From the perspective of the research method, Stosch et al. used a water ecological carrying capacity assessment method based on the ecosystem service-based ecological footprint (ESEF) to assess the regional water ecological carrying capacity [19]. In developing countries, population pressures and development patterns often endanger the integrity of river systems. An integrated approach to water management is essential. In Karimi and Ardakanian’s research, a new long-term water resource allocation model was developed. The model uses socio-economic parameters to consider the interaction of water supply and demand in the agricultural and industrial sectors. It includes production, arable land area, income and employment. The main advantage of this model is that it can reflect the relationship between the basic hydraulic system and the supply and demand components. The necessary components of the long-term water resource allocation model considering water supply are (1) water supply components; (2) water demands components (3) and the interactions between water supply and demand [20].

Men et al. proposed an index weight determination evaluation method based on the hierarchical analysis method [21] to calculate and evaluate the water environment carrying capacity. In order to avoid the subjective arbitrariness on the evaluation results of water resources carrying capacity, Cao et al. used the principal component analysis to evaluate the water resources carrying capacity [22]. Sun et al. used the system dynamics model to explore the source of the problem from the inside of the system, and analyzed the influencing factors of the water resources carrying capacity [23]. Doummar et al. developed and evaluated methods for water resources management in the Mediterranean.

Through the integrated management of water resources, there are ways to achieve multiple environmental, economic, and social benefits. The water resources model (WRM) is used to evaluate the efficiency of baseline model scenarios and the optimization process of different scenarios in river basins. Apply strengths, weaknesses, opportunities, and threat analysis to derive goals and constraints [24]. The flow of water resources, that is, the total flow, flood flow, base flow, seasonal and flood process line shape, seasonal and inter-annual changes are very important factors in the supply of water resources [25]. River water management must coordinate different needs. For water use, flood runoff must be stored and discharged according to different types of water use schemes. In order to prevent floods, there must be sufficient storage at the beginning of the flood period. In the management of lakes and reservoirs, water storage operations must be carried out in a way that does not increase the risk of flooding in riparian areas [26]. The results show that the best solution for water resources management is to reduce water consumption and demand, as well as losses and return.

It can be found from the literature that the estimation of the carrying capacity of water resources includes two important dimensions: supply and demand. In order to analyze the spatial-temporal evolution characteristics of regional water resources and the level of water resources carrying capacity, Wang et al. constructed a spatial Durbin model (SDM) and discussed the direct impact of different factors on water resources and spatial spillover effects [27]. Based on the traditional multi-objective analysis and decision-making
techniques, Li et al. proposed a scenario analysis method to reflect the level and status of the water resources carrying capacity of the Huaihe River Basin [28].

As summarized from the above literature, the research perspectives on water resources carrying capacity evaluation are becoming more and more abundant and the research methods are more and more diverse. Summarizing the management of water resources, most of them use multiple criteria decisions making (MCDM) to help decisionmakers choose feasible options. According to the attributes and characteristics of each plan, each plan is ranked according to its advantages and disadvantages to evaluate and select an ideal plan.

The factors of water management are very complex. There are many variables in the measurement model, which makes it difficult to estimate. Therefore, in this section, we conducted a literature review to evaluate which methods, theories, or concepts are used to quantify the human response to changes in the amount of water available. Its purpose is to use appropriate methods or theories through experience to provide useful information for water resources planning. This study summarizes the literature measurement model and aggregates various water resources management supply and demand indicators. In the empirical research, we used the principal component analysis (PCA) for the systematic analysis to carry out the demonstration of water resources carrying capacity. The increase in the variables of water resources management will lead to the complexity of system problems. In quantitative analysis, the principal component analysis method can reduce the variables involved and is an ideal tool for solving complex water resources carrying capacity factors.

3. Material and Methods
3.1. Overview of the Study Area

As the core city of the Huaihe River Eco-economic Belt, Huai’an City is located in the north-central part of Jiangsu, in the middle and lower reaches of the Huaihe River Basin, and is known as the Flood Corridor [29–31]. For this reason, this study selected Huai’an City for empirical research, and the scope of the study area is shown in Figure 1. There are many lakes and dense river networks in Huai’an City. Due to the superior natural conditions, the total amount of water resources in Huai’an City is relatively abundant, but the average amount of water resources occupied by each person is relatively insufficient [32–34]. In recent decades, the rapid urbanization development of Huai’an City has made certain achievements. The population has been increasing, and the industrial economy has been continuously agglomerating and consuming a lot of water resources [35]. However, due to weak environmental protection awareness, some enterprises discharge sewage and wastewater without processing, resulting in increasingly serious water environmental pollution [36] and an increasing pressure on water resources in Huai’an City. Therefore, a good evaluation of the carrying capacity of water resources is conducive to coordinating the relationship between economy and society and water resources in Huai’an City, and promoting sustainable economic and social development in the future.

3.2. Research Methods and Data Sources
3.2.1. Principal Component Analysis
In a multivariate statistical analysis, principal components analysis (PCA) is a method for statistical analysis and simplification of data sets. It uses an orthogonal transformation to linearly transform the observations of a series of potentially related variables, thereby projecting the data to a series of linear unrelated variables. These unrelated variables are called principal components [37–40]. Specifically, the principal component can be regarded as a linear equation, which contains a series of linear coefficients to indicate the projection direction. PCA is sensitive to the normalization or preprocessing of raw data (relative scaling). The principal component analysis is an important method in multivariate analysis and statistics by reducing dimensionality and replacing the original multidimensional variables with a few comprehensive variables [41–44]. The steps of PCA are as follows:
1. Normalization

Firstly, the original indexes are normalized to eliminate the influence of the evaluation index scale [45], as shown in Equation (1):

\[ X'_{ij} = \frac{x_{ij} - \bar{x}_j}{S_j} \quad (I = 1, 2, \ldots, n; \; S_j \neq 0) \]  

where \( X_{ij} \) is the original value of the \( j \)-th index of the \( i \)-th sample, \( X'_{ij} \) is the value after normalization, \( S_j \) and \( \bar{x}_j \) are the sample standard deviation and average of the \( j \)-th index.

2. The correlation coefficient matrix, as shown in Equations (2) and (3):

\[ R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1p} \\ r_{21} & r_{22} & \cdots & r_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ r_{p1} & r_{p2} & \cdots & r_{pp} \end{bmatrix} \]  

where

\[ r_{ij} = \frac{\sum_{k=1}^{p} (x_{ki} - \bar{x}_i)(x_{kj} - \bar{x}_j)}{\sqrt{\sum_{k=1}^{p} (x_{ki} - \bar{x}_i)^2 \sum_{k=1}^{p} (x_{kj} - \bar{x}_j)^2}} \]  

3. Calculation of eigenvalues and eigenvectors

To calculate the characteristic equation \(|\lambda I - R| = 0\), sort the eigenvalues in order of magnitude and find the eigenvectors \( a_i \) \((i = 1, 2, \ldots, p)\) corresponding to the eigenvalue \( \lambda_i \).

4. Calculation of the contribution rate and the cumulative contribution rate, as shown in Equations (4) and (5), respectively.

The contribution rate can be calculated as:

\[ P_i = \frac{\lambda_i}{\sum_{j=1}^{p} \lambda_j} \quad (i = 1, 2, \ldots, p) \]  

The cumulative contribution rate can be calculated as:

\[ P = \sum_{i=1}^{p} p_i \quad (i = 1, 2, \ldots, p) \]  

5. Calculation of the principal component load, as shown in Equations (6) and (7):

\[ l_{ij} = \sqrt{\lambda_j a_{ij}} \quad (i = 1, 2, \ldots, p; \; j = 1, 2, \ldots, m) \]  

\[ a_{ij} = \frac{l_{ij}}{\sqrt{\lambda_j}} \quad (i = 1, 2, \ldots, p; \; j = 1, 2, \ldots, m) \]  

6. Calculation of the comprehensive score value \( Z \) of the principal component, as shown in Equations (8) and (9):

\[ Z_i = a_{i1}X'_1 + a_{i2}X'_2 + \cdots + a_{ip}X'_p \quad (i = 1, 2, \ldots, m) \]  

\[ Z = \sum_{i=1}^{m} p_i Z_i \]
3.2.2. Data Sources

The data sources used in this study to analyze the water resources carrying capacity of Huai’an City are mainly three parts, the first part comes from the data published on Data Huai’an by the Huai’an Statistics Bureau [46], and the second part comes from the Huai’an Water Resources Bulletin issued by the Huai’an Water Resources Bureau [47], and the third part comes from the Huai’an Environmental Quality Bulletin issued by the Huai’an Ecological Environment Bureau [48,49].

4. Construction of Evaluation Index System for Water Resources Carrying Capacity

4.1. Principles of Evaluation Index Establishment

The following principles should be followed when constructing the evaluation index system of water resources carrying capacity in Huai’an City [34].

(1) Principle of feasibility: There are different levels of difficulties in obtaining data. Some index data are relatively easy to acquire, while some index data are more difficult to collect. Therefore, it is necessary to select the representative index data as much as possible according to the feasibility of data acquisition;

(2) Systematic principle: There are many factors that affect the carrying capacity of water resources, including economic, social, and water resources. In order to systematically and comprehensively reflect the status of water resources carrying capacity in Huai’an City, the indexes should be selected in accordance with systematic principles;

(3) Scientific principle: in order to scientifically reflect the current situation of water resources in Huai’an City, the selection of indexes should be objective on the one hand, and truthful on the other hand, avoiding both the omission of information and the overlapping of indicators.

4.2. Evaluation Index Selection

In this study, a large amount of relevant literature was analyzed and organized. Based on the foundation of previous studies [28,50,51], we fully analyzed the existing indicator system, referred to the criteria in the analysis of water supply and demand, combined with the current situation of Huai’an City, and selected 13 indexes [30,52–54] from four aspects, i.e., economic, social, environmental, and water resources [55–59],

where,

\[ X_1 \] is the total population (unit: ten thousand), which reflects the sum of the population within a certain area;

\[ X_2 \] is the regional GDP (unit: 100 million yuan), which reflects the economic strength and market size of the region;
$X_3$ is the investment in fixed assets (unit: 100 million yuan), which reflects the scale of investment in fixed assets in the region;

$X_4$ is the urbanization rate ($\%$), which reflects the level of urbanization in the region;

$X_5$ is the total water resources (unit: 100 million $m^3$) including surface water and groundwater in the area;

$X_6$ is the water supply volume (unit: 100 million $m^3$), which reflects the water supply capacity of the area;

$X_7$ is the amount of precipitation (unit: 100 million $m^3$), which reflects the regional precipitation status;

$X_8$ is the water consumption per 10,000-yuan GDP per capita (unit: $m^3$/10,000 yuan per capita), that is, the amount of water consumed per 10,000-yuan GDP per capita;

$X_9$ is the water consumption (unit: $m^3$ per capita), which reflects the per capita water consumption;

$X_{10}$ is the agricultural water consumption (unit: 100 million $m^3$), which reflects the consumption of agricultural water in the region;

$X_{11}$ is the industrial water consumption (unit: 100 million $m^3$), which reflects the consumption of industrial water in the region;

$X_{12}$ is the ecological environment water consumption (unit: 100 million $m^3$), which is the amount of water resources consumed for ecological environment restoration and construction;

$X_{13}$ is the residential water consumption (unit: 100 million $m^3$), which reflects the situation of residential water consumption.

5. Evaluation and Analysis of Water Resources Carrying Capacity in Huai’An City

5.1. Principal Component Results and Analysis

The IBM SPSS Statistics (SPSS) software \[60,61\] was used to perform a principal component analysis on the 13 index data of Huai’An City from 2013 to 2019 \[48\]. The correlation coefficient matrix of various water resources evaluation factors in Huai’An City (Table 1) and the cumulative contribution rate of principal components (Table 2) were obtained.

|                | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{12}$ | $X_{13}$ |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|----------|----------|----------|----------|
| $X_1$          | 1     |       |       |       |       |       |       |       |       |          |          |          |          |
| $X_2$          | 0.3533| 1     |       |       |       |       |       |       |       |          |          |          |          |
| $X_3$          | 0.4354| 0.9953| 1     |       |       |       |       |       |       |          |          |          |          |
| $X_4$          | 0.3988| 0.9986| 0.9990| 1     |       |       |       |       |       |          |          |          |          |
| $X_5$          | 0.6387| -0.3533| 1     |       |       |       |       |       |       |          |          |          |          |
| $X_6$          | -0.8987| -0.5298| -0.6012| -0.5698| 1     |       |       |       |       |          |          |          |          |
| $X_7$          | 0.7145| -0.0847| 0.0046| -0.0371| 0.9581| 0.9990| 1     |       |       |          |          |          |          |
| $X_8$          | -0.6843| -0.9092| -0.9419| -0.9262| -0.1410| 0.8319| -0.2900| 1     |       |          |          |          |          |
| $X_9$          | -0.8790| -0.6093| -0.6757| -0.6466| -0.5523| 0.9953| -0.6474| 0.8814| 1     |          |          |          |          |
| $X_{10}$       | -0.6899| 0.2404| 0.1579| 0.1982| -0.0903| 0.5926| -0.7934| 0.1506| 0.5288| 1     |          |          |          |
| $X_{11}$       | -0.5782| -0.8167| -0.8394| -0.8318| 0.0122| 0.7363| -0.0790| 0.8778| 0.7780| 0.0319| 1     |          |          |
| $X_{12}$       | -0.6923| 0.3845| 0.2974| 0.3369| -0.8234| 0.4994| -0.7707| -0.0010| 0.4218| 0.8098| 0.0426| 1     |          |
| $X_{13}$       | 0.2515| 0.9693| 0.9556| 0.9639| -0.3699| -0.4043| -0.1601| -0.8252| -0.4860| 0.4172| -0.7426| 0.4500| 1     |

From Table 1, it can be seen that some of the factors have correlation coefficients above 0.9, indicating that there is a strong correlation between the factors. Therefore, it is necessary to conduct a principal component analysis.
Table 2 shows that the cumulative contribution rates of the first and second principal components are 93.315%, which are greater than 85%. Thus, the first two principal components can comprehensively reflect the impact of the selected 13 index data on the water resources carrying capacity in Huai’an City. Then, the principal component load matrix and eigenvector matrix of the first two principal components were calculated. The principal component load matrix is shown in Table 3, and the eigenvector matrix is shown in Table 4.

Table 3. Principal component load matrix.

| Variables | L₁   | L₂   |
|-----------|------|------|
| X₁        | 0.773| −0.546|
| X₂        | 0.842| 0.529 |
| X₃        | 0.887| 0.447 |
| X₄        | 0.868| 0.486 |
| X₅        | 0.262| −0.929|
| X₆        | −0.899| 0.410|
| X₇        | 0.404| −0.836|
| X₈        | −0.988| −0.136|
| X₉        | −0.936| 0.325|
| X₁₀       | −0.257| 0.901|
| X₁₁       | −0.884| −0.203|
| X₁₂       | −0.151| 0.918|
| X₁₃       | 0.753| 0.626|

Table 4. Eigenvector matrix.

| Variables | L₁   | L₂   |
|-----------|------|------|
| X₁        | 0.108| −0.110|
| X₂        | 0.117| 0.107|
| X₃        | 0.124| 0.090|
| X₄        | 0.121| 0.098|
| X₅        | 0.037| −0.187|
| X₆        | −0.125| 0.083|
| X₇        | 0.056| −0.169|
| X₈        | −0.138| −0.027|
| X₉        | −0.130| 0.066|
| X₁₀       | −0.036| 0.182|
| X₁₁       | −0.123| −0.041|
| X₁₂       | −0.021| 0.185|
| X₁₃       | 0.105| 0.126|

From Table 3, it can be seen that the first principal component is in the same direction as the total population, regional GDP, fixed asset investment, and urbanization rate; while the first principal component is in the opposite direction of the agricultural water consumption, water supply, per capita water consumption, and per capita per 10,000-yuan GDP water consumption and industrial water consumption. These indicators are all related to the state of economic and social development. The second principal component is in the same changing direction as ecological environment water consumption and domestic water consumption, and is in the opposite direction of the total water resources and precipitation. This indicator mainly reflects the impact of water resources endowment. Therefore, the main factors affecting the carrying capacity of water resources in Huai’an City can be summarized as two main components: socio-economic development and water resources endowment.
5.2. Calculation of the Principal Component Comprehensive Score

First, the eigenvector matrix and the standardized index data were used to calculate the scores of the principal components L1 and L2, and then the comprehensive score L was calculated by multiplying the two principal component scores by their respective contribution rates and then adding the multiplication results of both components. The positive or negative values of the principal component score do not represent the true level of water resources carrying capacity, but can reflect the relative position of water resources carrying capacity. When the value of L is larger, the water resources carrying capacity is smaller, and vice versa [25]. In order to better display the dynamic changes in the water resources carrying capacity of Huai’an City from 2013 to 2019, the trend chart of the scores of each principal component is shown in Figure 2.

![Figure 2. Trend of the main component scores of Huai’an City from 2013 to 2019.](image)

From Figure 2, the water resources carrying capacity of Huai’an City shows a declining trend year by year from 2013 to 2019. The trend of the first principal component is basically consistent with the overall score. This is mainly because the contribution rate of the first principal component is as high as 55.194%, indicating that the first component is the main factor affecting the water resources carrying capacity of Huai’an City. The rapid urbanization process, economic development, and social development inevitably lead to the consumption of water resources. Although the development of science and technology, as well as the adjustment of policies and the gradual and rational allocation and utilization of water resources, have led to a yearly decrease in the water consumption per 10,000-yuan GDP per capita between 2013 and 2019, the scale of decrease is not large enough to offset the consumption of water resources in the rapid urbanization process. Therefore, the first principal component shows a decreasing trend. The contribution rate of the second principal component is 38.121%.

The second principal component showed an upward trend from 2013 to 2015, but it began to gradually decline after 2015. The second principal component mainly reflects the water resources endowment of Huai’an City, so it is mainly affected by factors such as total water resources and precipitation. From 2013 to 2019, the average value of total water resources in Huai’an City is 3.802 billion m³, and the average value of precipitation is 9.712 billion m³. In 2015, the total amount of water resources and precipitation in Huai’an City were both the highest from 2013 to 2019, which were 5.4272 billion m³ and 11.8419 billion m³, respectively. Thus, the second component had the highest value in 2015. In 2019, the total water resources and precipitation in Huai’an City were at the lowest in the past years, so the second principal component had the lowest value in 2019.
In summary, the water resources carrying capacity of Huai’an City is under increasing pressure in general. Therefore, it is necessary to take further active measures to promote the coordination of economic society and water resources.

6. Conclusions and Enlightenment

Based on the method and theory review of water resources carrying capacity, this study evaluated and analyzed the water resources carrying capacity of Huai’an City according to the status of water resources in Huai’an City. In addition, based on the evaluation results, suggestions and measures were proposed to improve the water resources carrying capacity of Huai’an City, thus providing a reference for the coordinated development of the economy, society, and water resources in Huai’an City. Follow-up research can be based on the analysis model developed in this research for long-term monitoring, which can be used as a reference for water resources management policies.

6.1. Conclusions

According to the analysis results, since 2013, the water resources carrying capacity of Huai’an City has shown a downward trend year by year. This is mainly due to the rapid economic and social development of Huai’an City and the impact of water resources. Huai’an City carried out the construction of a water-saving city and water-saving society after the 12th Five-Year Plan, and invested a lot of human and material resources in water-saving technology transformation. However, due to the late start, the returns need a certain period of time to be effective, so the overall trend is downward. Therefore, Huai’an City should further strengthen the importance of water resources protection, increase investment in policies, construction and environmental protection awareness, and strive to offset the negative impact of economic and social development on water resources as soon as possible, thereby increasing the water resources carrying capacity of Huai’an City and promoting the coordinated development of economy, society and environment.

6.2. Suggestions and Countermeasures for Sustainable Development of Water Resources in Huai’an City

The condition of water resources is closely related to human society, economic development, and environmental health. The rational use of water resources not only can promote local economic and social development, but also does not put pressure on the future demand for water resources. Therefore, Huai’an City must adopt a series of measures to promote the sustainable development of water resources.

1. Establish a water ecological security pattern and formulate water resources protection policies in different regions:
   Huai’an City should establish a water ecological security pattern under the condition of understanding the local water resources base to provide a basis for the formulation of water resources protection policies in districts. Through the superposition analysis of water conservation patterns, water environment patterns, and storm flood regulation safety patterns, a comprehensive water ecological security pattern can be obtained. In addition, according to the spatial analysis of the water ecological security pattern, we should divide this region into protected zone, buffer zone, and control zone. According to different zoning characteristics, different localized policy guidance can be provided to precisely regulate and improve the efficiency of water resources protection and utilization;

2. Improve infrastructure construction and speed up water resources management:

   The total amount of water resources is affected by uncertain factors such as precipitation. These variables cannot be controlled. However, the protection and utilization of existing water resources can be strengthened through the construction of water conservancy projects. For example, the development of small reservoirs, the use of rivers, lakes, wetland parks, and the construction of sponge cities play a role in water storage, which can be used in the case of reduced precipitation or water scarcity. At the same time, we should
coordinate the allocation of water resources between water-abundant areas and arid areas to solve the water shortage phenomenon due to spatial-temporal differences. We should also speed up the treatment of water pollution, resolutely combat the illegal discharge of water pollution, and reduce the negative impact of population and socio-economic development through the treatment of water resources;

3. Adjust industrial structure and promote the technological update:

Huai’an City should change the original industrial development model, stimulate industrial structure upgrading by eliminating enterprises with serious water pollution and high water consumption, improve water resource utilization efficiency through technological optimization, encourage the development of low water consumption industries, implement a water-saving economy, explore the road of water-saving economic development (e.g., adopt advanced means such as drip and sprinkler irrigation in agricultural irrigation to reduce the waste of water resources in agricultural water use), and strengthen the process management of water consumption in industrial development. In addition, enterprises should invest certain funds and manpower to develop water-saving processes and strengthen water recycling and sewage treatment, which can not only save the environmental protection costs of enterprises but also enhance their competitiveness.

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