

# Research on urban ecosystem health evaluation of Yunnan Province based on principal component analysis method

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## ABSTRACT

Urban ecosystem consists of environment, social culture and economy, and the health of urban ecosystem determines the quality of life of residents and is an important dependence of human life. Through the official statistics of Yunnan Province in the past five years, a number of subdivided indicators of urban data are selected and dimensionality is reduced using principal component analysis to obtain the urban ecosystem health evaluation system, which makes a comprehensive assessment of the health and development of the ecosystems in Yunnan Province and puts forward suggestions for it. The results show that the overall development of urban ecosystem health in Yunnan Province has been steadily improving over the past five years, with a balanced development in all aspects, and that the future management mode should emphasize the coordinated development of the economy and the ecological environment.

## KEYWORDS

Urban ecosystem health; Principal component analysis; Comprehensive evaluation system.

## 1. INTRODUCTION

Currently, under the background of ecological civilization construction and "double carbon", in order to cope with climate change, air pollution, heat island effect and other urban ecological problems, the green ecological orientation of urban planning has become more and more prominent. Urban ecosystems provide diverse ecosystem services for cities, and the study of Urban Ecosystem Services (UES) can help to promote the planning and construction of green ecological cities. Domestic and international UES-related research began to appear clearly around 2000, and has gradually become a hot spot since 2010, and has begun to be applied to spatial planning fields such as territorial spatial planning, urban and rural planning, to support the values, strategies, policies, coordination and operationalization of spatial planning[1]. Healthy ecosystems guarantee the sustainable development of human beings, and the state of urban ecosystem health can be used as an important monitoring indicator for sustainable urban development[2]. Urban spatial planning and ecosystem services are mutually based and synergistically optimized[3]. Urban ecosystems are artificial ecosystems within the urban space formed by the interaction of residents with the natural and social environments, with high openness, instability, vulnerability and complexity [4]. With the accelerated pace of social development and rural urbanization, urban ecological health has become an important factor affecting human life, and its stable development can improve the quality of life of urban residents and promote the economic level, and the construction of a comprehensive urban ecosystem health assessment system can enable the city to achieve a virtuous cycle of development under the guidance of a more scientific and healthy[5]. In this paper, we will start from the three major dimensions of environment,

social culture and economy, select 12 subdivided indicators, and make an evaluation of the ecosystem health of Yunnan Province by using principal component analysis.

## 2. LITERATURE REVIEW

### 2.1. Overview of foreign research on urban ecosystems abroad

**Table 1.** Synthesis of foreign studies on urban ecosystems at home and abroad

<b>external (affairs)</b>		
Urban ecosystem valuation studies	<p>Barricoll et al. evaluated the composition and diversity of three landscape types (school trees, oaks and olive trees) in relation to the wider environment in an urban green space in the city of Coimbra, central Portugal[6].</p> <p>Tehrani NA et al. evaluated the ecological thresholds of 115 urban areas in Tehran by modeling the number of urban carrying capacity loads based on the concept of carrying capacity and the principle of sustainability[7].</p> <p>Alam M et al. conducted an evaluation study of urban ecosystems, in general and in part, using indicators specific to land use type or ecological service status[8].</p> <p>Shen J et al. conducted an ecosystem vulnerability assessment of Beijing[9].</p> <p>Ossola A (et al. An evaluation of the current habitat complexity of urban parks, Bairan Reserve, Australia[10].</p> <p>Jerry et al. established the Havana Urban Ecosystem Evaluation System using the Driver-Pressure-State-Exposure-Impact-Response model[11].</p>	<p>In terms of urban ecosystem assessment studies, most of them are concentrated in developed countries or regions, and there are fewer studies on urban ecosystem assessment in remote and backward areas; and most of the urban ecosystem assessment studies are concentrated on the assessment of ecosystem services or biodiversity and other single aspects, and there are fewer comprehensive assessments of urban ecosystems as a whole.</p>
<b>internal (a country)</b>		
Urban Ecosystem Health Assessment Study	<p>Shang Zhihai et al. conducted a study to evaluate the ecosystem health of Meijiang District, Meizhou City from 2000 to 2004 based on five elements and combined with hierarchical analysis.</p> <p>Li Mengjie et al. used the fuzzy mathematical method to make a dynamic evaluation of the health form of the ecosystem in Nanjing in terms of vigor and resilience [12].</p> <p>Gao Cailing et al. evaluated the health of urban ecosystems in Jiaozuo City based on the entropy weight method to assess the systematic health evaluation[13].</p> <p>Liu Peide et al. selected indicators from five aspects of vitality-organizational structure-resilience-ecosystem service function and ecosystem cognition, and evaluated the health of ecosystems in Dongying City with the method of Mixed Indicator Value TODIM [14].</p> <p>Ouyang Xiao et al. assessed based on ecosystem services and ecosystem health using the moisture value method[15].</p> <p>Jiaqi Li, Dajuan Wan, Ting Liu et al. Urban ecosystems around ChangZhuTan Health was systematically evaluated[16].</p>	<p>In the health evaluation of urban ecosystems, domestic researchers mainly select studies within a certain time span of the study area to evaluate the health status of urban ecosystems, and the analytical methods are more diverse, but there is a greater similarity in the selection of health evaluation indexes, and there are more studies that take vitality, organizational structure, restorative power, ecosystem service function and population health as the evaluation index system.</p>

## 2.2. Methods for evaluating the health of urban ecosystems in China

**Table 2.** Comparison of urban ecosystem health assessment methods in China

Evaluation methodology	specificities	vantage	drawbacks
AHP hierarchical analysis	Decision-relevant metasomes can be decomposed into guidelines, objectives, and program levels for quantitative or qualitative studies.	The method is simple and easy to use and has more applications.	The indicator assignment step is highly subjective and can easily lead to research deviating from objective facts.
fuzzy mathematical evaluation method	The fuzzy relationship is constructed by establishing the affiliation function through the data, and the weight information contained in each factor is used to obtain the fuzzy set by combining the affiliation matrix, and the fuzzy quantization work is carried out by reducing the influence of uncertain factors to obtain the evaluation results.	For more fuzzy and difficult to quantify factors, the fuzzy mathematical method can be quantitative research on the interrelationships of its internal components, which helps to solve the overall evaluation of uncertainty.	Determination of criteria and affiliation functions of evaluation indicators for fuzzification is subject to a certain degree of subjective interference.
Gray predictive correlation method	The urban ecosystem is viewed as a gray system, and the theory of gray system modeling is used to evaluate the information in the urban ecosystem that is either certain or uncertain.	The ability to show the uncertainties contained in urban ecosystems and to quantitatively express their dynamics.	The low level of differentiation between the model partition coefficients within the methodology, as well as the inability to exclude large subjective influences in the process of determining the partition coefficients, can easily lead to a decrease in the precision of the results of the study.
energy value analysis (EVA)	Using solar energy as a reference standard, the characteristics of urban ecological and economic systems are presented in terms of energy, so as to discover the characteristics of the urban system structure and functional energy data, and thus reflect the state of urban ecosystem health.	By applying the concept of energy flow in urban systems to the problem of health assessment of urban ecosystems, it is possible to quantitatively evaluate the methods of each assessment indicator.	The energy value conversion process is prone to large errors, and the conversion of energy values for various types of indicators relies on human operational experience, which is less accurate and more controversial.

## 3. OBJECTS OF STUDY AND RESEARCH METHODOLOGY

### 3.1. Objects of study

In order to evaluate the ecological health of cities in Yunnan Province in a multi-dimensional way, the original data for the article was taken from the 2017-2021 Yunnan Provincial Statistical Yearbook provided by the Yunnan Provincial Bureau of Statistics, and the last five years were selected to be related to the environment, socio-cultural, and economic

A number of indicators are relevant, including air quality, employment, gross domestic product per capita, and so on.

### 3.2. Research methodology

Through literature analysis this paper proposes to use principal component analysis (PCA) to conduct research. PCA is a data analysis method that combines a group of indicators or variables with correlation into a new mutually independent composite indicator with the help of orthogonal

transformation. A few main components are extracted from the original variables, and the main components need to retain as much as possible the basic information of the original variables and have no correlation with each other. The basic steps of the principal component extraction method are: standardization of the original data; determination of the relevance of the standardized indicators; and determination of the principal components. When the cumulative contribution rate of the variance of the sub-components is large enough, the main components can be retained, and the sub-components with lower contribution rate of the subsequent information can be eliminated; the obtained main components are weighted and summed to obtain the final evaluation results[16].

## 4. URBAN ECOSYSTEM HEALTH EVALUATION SYSTEM IN YUNNAN PROVINCE

### 4.1. Selection of indicators

**Table 3.** Ecosystem Health Evaluation Indicator System Table

evaluation layer	indicator layer	vintages					hidden meaning	notation
		2017	2018	2019	2020	2021		
matrix	Respirable particles/( $\mu\text{g}/\text{m}^3$ )	43.875	46.375	38.5	33.375	34	environmental quality	X1
	Sewage treatment rate/%	91.31	92.39	94.49	96.22	96.87	emission	X2
	Urban greening coverage/%	36.96	38.15	39.03	39.88	41.78	Residential environment	X3
	Non-hazardous treatment rate of domestic waste/%	92.7	98.2	99.8	100	100	environmental quality	X4
economics	Total retail sales of consumer goods/billion dollars	8194.79	9197.26	10158.23	9792.87	10731.8	Level of economic development	X5
	GDP per capita/\$	39458	44446	49323	52047	57686	Level of economic development	X6
	Growth rate of investment in fixed assets/%	17.47	11.3	8.3	7.2	4.6	Urban potential	X7
	Disposable income per inhabitant/\$	30996	33488	36238	37500	40905	Level of economic development	X8
sociocultural	Resident population/million	4693	4703	4714	4722	4690	urban subject	X9
	Number of hospital beds/(beds/thousand population)	210.8	223.3	241.3	252.5	256.1	Residents' livelihood security	X10
	Employees/million	2831	2822	2812	2806	2774	social stability	X11
	Number of students enrolled/million	748.61	728.62	746.95	765.17	774.72	Socio-educational level	X12

The health of urban ecosystems consists of three major dimensions: environmental, socio-cultural, and economic, involving all aspects of residents' lives. At the natural level, human activities on the environment, including air pollution, green coverage, garbage disposal, etc., determine the basis of people's survival in the city [17]; at the socio-cultural level, factors such as employment, education, medical care, etc., are the key to ensure the basic living standard of urban residents, reflecting the degree of civilization and the level of development of the city; at the economic level, the gross domestic product per capita, the income of the residents, etc., directly reflect the current construction level and future development potential of the city. level and future development potential[18]. Based on the 2017-2021 Yunnan Provincial Statistical Yearbook and the actual situation of Yunnan

Province, the article selects 12 subdivided indicators including urban green coverage, resident population, per capita GDP and so on in five years, as shown in Table 3.

## 4.2. Modeling using principal component analysis

### (1) Data standardization and correlation analysis.

As the indicators are related to areas with large differences, the units and orders of magnitude are not uniform, and it is impossible to carry out a comprehensive analysis. Therefore, it is necessary to standardize the raw data and obtain standardized data as shown in Table 4. In order to analyze whether there is a high degree of correlation between the indicators, the article carries out correlation analysis of the indicators. Correlation analysis can measure the correlation between two indicators, and the size of the correlation coefficient can quantify the degree of correlation between indicators. When the correlation coefficient is large, the principal component analysis method is of practical significance. The article carries out correlation analysis on 12 indicators of urban ecosystem, and the results are shown in Table 5. The correlation coefficients are  $[-1,1]$ , and Table 5 shows that the absolute value of correlation coefficients between most pairs of indicators is larger, i.e., the correlation between the indicators selected in the article is larger.

significant, so the results of the subsequent principal component analysis have high confidence.

**Table 4.** Results of data normalization by indicator, 2017-2021

norm	particular year				
	2017	2018	2019	2020	2021
X1	0.80103	1.23169	-0.12489	-1.00775	-0.90008
X2	-1.23109	-0.77977	0.09778	0.82072	1.09235
X3	-1.20833	-0.55473	-0.0714	0.39545	1.43901
X4	-1.73615	0.01915	0.52978	0.59361	0.59361
X5	-1.46376	-0.43054	0.5599	0.18334	1.15106
X6	-1.30555	-0.59261	0.1045	0.49384	1.29983
X7	1.56181	0.30968	-0.29913	-0.52236	-1.05
X8	-1.27307	-0.61615	0.10877	0.44144	1.33901
X9	-0.83747	-0.10285	0.70523	1.29293	-1.05785
X10	-1.34376	-0.69772	0.23257	0.81143	0.99749
X11	1.01049	0.59711	0.13779	-0.13779	-1.6076
X12	-0.23594	-1.35782	-0.3291	0.69345	1.22942

### (2) Principal component extraction.

The correlation matrix in Table 5 was calculated to obtain the eigenvalues of the matrix as well as the contribution rate and cumulative contribution rate of the eigenvalues. The information contribution rate of Z1 is 81.278% and that of Z2 is 11.955%, and the cumulative information contribution rate of the two amounts to 93.233%, so Z1 and Z2 are retained as the principal components of the final evaluation, and the rest of the components with lower contribution rates are eliminated.

### (3) Determine the assessment model.

After determining Z1 and Z2 as the three main components, the final assessment model can be obtained based on the eigenvector calculation results and variance contribution ratio of Z1 and Z2.

Firstly, the factor loading matrix between the two principal components and each index is obtained, as shown in Table 6. The larger the absolute value of the matrix value indicates the larger the influence of the principal component on the original indicator.

**Table 5.** Correlation matrix

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1	1	-0.942	-0.834	-0.641	-0.748	-0.864	0.785	-0.861	-0.309	-0.92	0.778	-0.906
X2	-0.942	1	0.952	0.827	0.9	0.976	-0.942	0.971	0.271	0.994	-0.891	0.807
X3	-0.834	0.952	1	0.785	0.924	0.991	-0.939	0.993	0.002	0.938	-0.982	0.776
X4	-0.641	0.827	0.785	1	0.905	0.844	-0.949	0.828	0.491	0.879	-0.677	0.338
X5	-0.748	0.9	0.924	0.905	1	0.953	-0.973	0.953	0.171	0.924	-0.884	0.572
X6	-0.864	0.976	0.991	0.844	0.953	1	-0.969	0.999	0.123	0.972	-0.954	0.755
X7	0.785	-0.942	-0.939	-0.949	-0.973	-0.969	1	-0.962	-0.279	-0.964	0.87	-0.586
X8	-0.861	0.971	0.993	0.828	0.953	0.999	-0.962	1	0.09	0.965	-0.963	0.763
X9	-0.309	0.271	0.002	0.491	0.171	0.123	-0.279	0.09	1	0.339	0.178	-0.075
X10	-0.92	0.994	0.938	0.879	0.924	0.972	-0.964	0.965	0.339	1	-0.864	0.744
X11	0.778	-0.891	-0.982	-0.677	-0.884	-0.954	0.87	-0.963	0.178	-0.864	1	-0.792
X12	-0.906	0.807	0.776	0.338	0.572	0.755	-0.586	0.763	-0.075	0.744	-0.792	1

**Table 6.** Principal Component - Raw Indicator Component Matrix

Evaluation level	Evaluation indicators	ingredient	
		Z1	Z2
matrix	Respirable particles/( $\mu\text{g}/\text{m}^3$ )	-0.899	0.001
	Sewage treatment rate/%	0.99	0.04
	Urban greening coverage/%	0.977	-0.174
	Non-hazardous treatment rate of domestic waste/%	0.852	0.441
economics	Total retail sales of consumer goods/billion dollars	0.946	0.072
	GDP per capita/\$	0.996	-0.056
	Growth rate of investment in fixed assets/%	-0.968	-0.158
	Disposable income per inhabitant/\$	0.993	-0.088
sociocultural	Resident population/million	0.197	0.93
	Number of hospital beds/(beds/thousand people)	0.989	0.13
	Employees/million	-0.929	0.345
	Number of students enrolled/million	0.77	-0.407

As can be seen from Table 4, the first principal component Z1 in the economic factors part of the factor loading value coefficient results in a larger, so Z1 named economic components; the second principal component Z2 in the environmental factors part of the factor loading value coefficient is more. According to the contribution rate of each principal component and the cumulative contribution rate, you can get their respective to the results of factor loading value coefficients, and finally derived from the Yunnan Province, the urban ecosystem health of the comprehensive evaluation system of the calculation of the formula. The calculation formula for the comprehensive evaluation system of urban ecosystem health in Yunnan Province is finally derived as follows:

$$Z=0.81278Z_1+0.11955Z_2 \quad (1)$$

Eq. 1 is the formula for the comprehensive evaluation system of urban ecosystem health in Beijing, where Z1 and Z2 represent the weights accounted for by the corresponding indicators of each

principal component, and Z represents the total score of the calculation, i.e., the final score of the evaluation system of urban ecosystem health in Yunnan Province in that year.

### 4.3. Calculation of Comprehensive Score of Urban Ecosystem Health in Yunnan Province

Based on the results after standardization of the raw data (Table 4) and the formula for urban ecosystem health evaluation (Eq. 1), the matrix of component score coefficients was used to calculate the comprehensive score of urban ecosystem health in Yunnan Province from 2017 to 2021. The component score coefficient indicates the relationship between each indicator and the extracted component, and a high component score indicates a closer relationship between the indicator and the component. The matrix of component score coefficients can be used for the linear combination of principal components, i.e., to calculate the weights of components in the composite score. The principal component-primitive indicator component score coefficients are shown in Table 7. Based on the component score coefficients in Table 7, the formula for calculating the principal component Z1 and Z2 scores can be obtained:

$$Z_i = \sum_{j=1}^{12} X_j \times Z_{ij} \quad (2)$$

Where: i-component number, i.e., the ith principal component; j-indicator number, i.e., 1-12 raw indicators;  $X_j$  - the standardized value of the jth class of indicators;  $Z_{ij}$  - component score coefficient of the ith principal component on the jth original indicator.

**Table 7.** Matrix of component score coefficients

Indicator level	Evaluation indicators	ingredient	
		1	2
matrix	Respirable particles/( $\mu\text{g}/\text{m}^3$ )	-0.287866137	0.000834784
	Sewage treatment rate/%	0.317004978	0.033391355
	Urban greening coverage/%	0.312842287	-0.145252394
	Non-hazardous treatment rate of domestic waste/%	0.272816406	0.368139687
economics	Total retail sales of consumer goods/billion dollars	0.302915868	0.060104439
	GDP per capita/\$	0.318926221	-0.046747897
	Growth rate of investment in fixed assets/%	-0.309960423	-0.131895852
	Disposable income per inhabitant/\$	0.317965599	-0.073460981
sociocultural	Resident population/million	0.063080789	0.776349
	Number of hospital beds/(beds/thousand population)	0.316684771	0.108521903
	Employees/million	-0.297472348	0.288000436
	Number of students enrolled/million	0.246559428	-0.339757036

The weights of the scores on the principal components of urban ecosystem health in Yunnan Province in a given year can be calculated respectively by equation (2). Using the comprehensive score calculation formula in equation (1), the evaluation score of urban ecosystem health in Yunnan Province from 2017 to 2021 was obtained. As shown in Table 8.

**Table 8.** Comprehensive score of ecosystem health in Yunnan Province

particular year	Z1	Z2	Z
2017	-4.06	-1.64	-3.5
2018	-2.12	0.21	-1.7
2019	0.52	0.91	0.53
2020	1.9	1.1	1.68
2021	3.76	-0.58	2.99

## 5. ANALYSIS OF RESULTS

From the development trend of the comprehensive score in Table 8, it can be seen that the urban ecosystem health score of Yunnan Province has been on an increasing trend in the past five years. According to the strategic development layout of Yunnan Province in the past five years, the analysis results are obtained: the comprehensive score of 2017-2018 is improved from -3.5 to 0.53, and the development growth rate has been significantly improved. The score of 2019-2021 is improved from 0.53 to 2.99, and the growth rate is significantly slowed down compared with the previous year, and the economic growth rate of China in that year generally declined, but the comprehensive score did not decline, indicating that Yunnan Province is in a leading position in the development of cities in China; overall, the situation improved considerably in 2017-2021, and the comprehensive score improved year by year.

## 6. CONCLUDING REMARKS

Changes in each aspect of the urban ecosystem will affect other parts of the system, and only comprehensive management can realize sustainable development of urban ecosystem health. Yunnan Province's current urban health is generally showing a steady improvement, so the government should build on the existing foundation to strengthen all aspects of construction. At the economic level, it should advocate the coordinated development of economic strength and ecological protection, prevent the phenomenon of sacrificing the natural ecology in order to accelerate economic development, and promote the good cycle of urban ecological health with the goal of optimizing the environment, economy, and society and culture together. At the social level, in the face of the current phenomenon of employment and talent saturation in Yunnan Province, the government should focus on industrial reform, such as attracting a large number of talents by accelerating the construction of Xiongan New Area, encouraging the development of emerging industries, and guiding talents to start their own businesses, etc.; at the environmental level, it attaches importance to the dissolution of the non-capital functions, and promotes the protection and development of ecological conservation areas, and the healthy development of the ecological health is the key to improving the health of the city. In order to enhance the level of urban ecological management, the government should formulate a reasonable and scientific urban ecological development plan, revise and update it with the changing actual situation every year, and always manage the city from the perspective of sustainable development.

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