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Comprehensive evaluation of eco city construction based on principal component analysis—Take Shangluo City, Shaanxi Province as an example

Jie Xiao, Guozhang Zheng, Yue Luo*

School of Geographical Sciences, Shanxi Normal University, Linfen 041000, Shanxi, China. E-mail: shanxizgz@126.com

ABSTRACT

In order to explore the development of ecological city in Shangluo City, principal component analysis and evaluation index system are used to analyze the overall development level, coordination degree of various subsystems, development level and influencing factors of Shangluo ecological city construction, in order to provide constructive suggestions for regional development and planning of Shangluo City. Research shows: From 2005 to 2015, the construction of Shangluo eco city showed a trend of differentiation, with good economic and environmental development, while the social construction developed slowly, and the economy, society and environment could not develop harmoniously. In the process of building a good, coordinated and unified ecological city in Shangluo, we need to be based on reality, develop strengths and avoid weaknesses, maximize the healthy and efficient development of economy and society in Shangluo, and better take the road of sustainable development.

Keywords: ecological city; principal component analysis; comprehensive evaluation; Shangluo

1. Introduction

Shangluo is one of the few poverties concentrated and contiguous areas in China, and it is also one of the water intakes for the middle route of the South-to-North Water Transfer Project[1]. With the in-depth development of industrialization and urbanization, a series of problems such as ecological damage and resource depletion have become increasingly prominent. The construction of ecological city with coordinated and sustainable development is an urgent need of the local government. In recent years, eco city research has become a hot topic for domestic and foreign scholars to study urban sustainable development. For example, Zeng[2] pointed out that the theoretical research of eco city construction is insufficient in the evaluation of eco city, which plays an important role in the later theoretical research of eco city development. Qin[3] discussed the connotation, construction system and measurement method of ecological civilized city from the perspective of geography, and made an empirical analysis combined with specific regions. Through the evaluation of ecological city construction in Xi'an, Li[4] provides thinking for the research of ecological city construction in a specific

area. On the research of Shangluo ecological city, Li[1] measured the current situation of urban development in Shangluo by fragmentation index method, which provides a theoretical reference for Shangluo urban development[5,6]. Evaluated and studied the ecological sustainable development level and ecological process of Shangluo City, obtained the problems existing in the ecological sustainable development of Shangluo City, and put forward constructive suggestions. This paper uses the principal component analysis method and constructs the evaluation index system of eco city development level to evaluate and analyze the construction of Shangluo eco city, in order to provide decision-making reference for Shangluo in the construction of eco city.

2. Overview of the study area

Shangluo is located in the southeast of Shaanxi province and the city of Zhongshan valley in the hinterland of Qinling Mountains. The city governs six counties and one district, with a total area of 19,293 km², accounting for 94% of the area of Shaanxi province. The territory has complex landform structure, vertical and horizontal gullies, high terrain in the northwest and low terrain in the southeast. It extends from northwest to Southeast and is distributed in a palm shape. It is known as "eight mountains, one water and one field" with dense rivers, it crosses the Yangtze River and Yellow River basins and is located in the transition zone between warm temperate zone and north subtropical zone. It has a semi humid mountain climate; wild Chinese medicinal materials are rich in resources, many kinds and large reserves; it is also famous for raw lacquer, tung oil, walnut, chestnut, persimmon, agaric and other forest products[7]. At the end of 2015, the total population of the city was about 2.52 million, the annual GDP of the city was about RMB 62 billion, and the total financial revenue of the city was about RMB 4.5 billion[8]. Guided by the strategy of building the most beautiful western landscape city in China, Shangluo put forward the goal of building an ecological city during

the Eleventh Five Year Plan period, and took the construction of an ecological city as a major development strategy of Shangluo under the background of sustainable development in the 12th Five Year Plan[9].

3. Research methods and data sources

3.1. Selection of indicators

According to the evaluation system involved in the current research papers on sustainable development and eco city evaluation, select the highly targeted, important, scientific indicators that reflect the connotation, characteristics, basic factors and main problems of eco city, can reflect the essence and connotation of eco city, and have positive and negative indicators as the basis[4,10].

3.2. Research methods

1) In order to eliminate the difference between different variables, range standardization is used to standardize the data.

Positive indicators:

$$Y_{ij} = \frac{X_{ij} - X_i min}{X_i max - X_i min}, i = 1,2,3,\cdots,n; j = 1,2,3,\cdots,m \tag{1}$$

Negative indicators:

$$Y_{ij} = \frac{X_i max - X_{ij}}{X_i max - X_i min} \tag{2}$$

Where Y_{ij} is the standardized value of each index, X_{ij} is the actual value of the index, X_{imax} and X_{imin} are the maximum and minimum values of index i respectively, and i and j are index series and time series respectively.

2) The principal component analysis method[3,10–12] is used to give the weight to the indexes of

economic, social and environmental subsystems respectively. According to the score coefficient in the principal component load matrix, the principal component score and comprehensive score are obtained by regression method, and then the development level of Shangluo ecological city is analyzed and evaluated.

3.3. Data sources

The basic data comes from the statistical yearbook of Shangluo City from 2006 to 2016, urban environmental quality report, statistical bulletin, survey data of government departments, etc.[8]

4. Evaluation and analysis of ecological city construction in Shangluo City

4.1. Comprehensive evaluation and analysis

Eco city construction is a system engineering involving a complex dynamic open giant system composed of subsystems such as economy, society, population, science and technology, resources and environment. Therefore, eco city construction should not only pay attention to the overall development level of eco city, but also pay attention to the development of economic, social and environmental systems and the coordinated development of "economy, society and environment"[3,11]. SPSS 17.0 is used to conduct principal component analysis from three aspects of economic, social and environmental systems, and the scores of each system are obtained: The score of Shangluo ecological city construction level is increasing year by year. Among them, the economic subsystem presents a state of rapid development. The score of social subsystem stagnated from 2009 to 2011, which is related to the social effects of industrial adjustment and upgrading in Shangluo area to implement the Eleventh Five Year Plan. Shangluo has finally established four major industries with modern materials, traditional Chinese medicine resources, green food and ecotourism as the pillars[1,13], which will further promote the economic and social develop-

ment of Shangluo. The score trend of environmental subsystem developed rapidly before 2007 and after 2010, but stagnated from 2007 to 2010, which is related to the radiation of Guanzhong and Guanzhong Tianshui Economic Zone and Shangluo's active undertaking of industrial transfer (**Figure 1**). Shangluo is a city in Zhongshan valley, which mainly develops agriculture and sightseeing tourism. Its economic development level is low and its foundation is weak. Its extensive development and environmental pollution have become more and more serious in recent years. Therefore, coordinating economic development and environmental governance requires a long-term process.

For the overall level comprehensive score, the construction level of ecological city in Shangluo City shows a continuous upward trend, and the development speed is fast, indicating that the construction pace of ecological city in Shangluo is steadily improving. Through linear trend fitting, it is found that the R^2 value is 078, the linear fitting effect is good, and the growth trend is significant. However, the development rate slowed down between 2011 and 2015, which is related to the intensification of pollution caused by mining, metal smelting and urbanization with the development of economy. The lack of investment in pollution control and environmental protection will also affect the ecological construction level of Shangluo City to a certain extent (**Figure 2**).

On the whole, Shangluo's ecological urban construction is developing in a good trend. Especially after 2009, under the influence of the strategic guidance of building the most beautiful western landscape city in China and the objectives of the eleventh five year plan, Shangluo's urban construction takes ecological protection as the core, adheres to the sustainable development strategy, studies the coordinated development of urban construction and ecological environmental protection, and adheres to the policy of "paying equal attention to ecological city construction and resource ecological protection". Adhere to the strategy of adjusting measures to local conditions and time conditions, and take the

four major industries of modern materials, traditional Chinese medicine resources, green food and ecotourism as the pillar[1,13]. At the same time, timely assess whether the environmental pollution exceeds the local environmental capacity, strictly control the environmental quality of the Danjiang River basin where Shangluo is located, and improve the quality of human settlements[1]. With the gradual implementation of the plan, the overall level of Shangluo eco city construction has been steadily improved, and the ecological awareness of residents and enterprises has been gradually strengthened, which will lay a good foundation for Shangluo to build the most beautiful western landscape city in China. It can be predicted that the construction level of Shangluo Eco city will be rapidly raised to a higher level in the future.
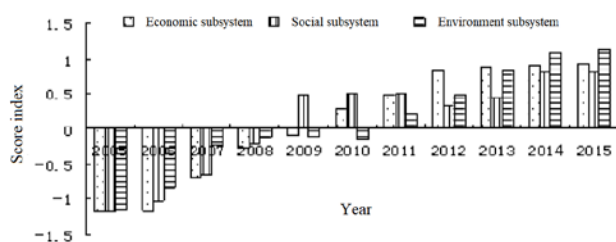

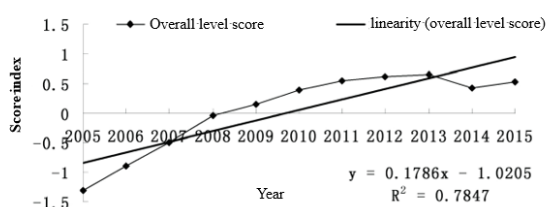**Figure 1.** The various subsystems score changes of the eco-city construction during 2005–2015 in Shangluo.

Figure 2. The comprehensive score and regression analysis of the eco-city during 2005–2015 in Shangluo.

4.2. Coordination analysis

The radar chart is used to analyze the coordination of the development of Shangluo eco city from 2005 to 2015[4,11]. It is concluded that the comprehensive capacity of Shangluo eco city construction presents a differentiation trend, and the economy, society and environment cannot develop harmoniously for a long time. Among them, the scores of the economic and social subsystems of Shangluo eco city construction from 2005 to 2009 are relatively low, while the scores of the environ-

mental subsystem are high, indicating that the primitive ecology of Shangluo is maintained well from 2009 to 2015, the economic and environmental scores increased rapidly, while the social scores were low, indicating that Shangluo's ability to deal with the relationship between economic development and environmental protection was enhanced, but the social problems brought by extensive economic development were ignored (**Figure 3**). On the whole, in the construction of Shangluo eco city, the degree of ecological coordinated development of economy, society and environment is still low, and the score growth rate of economy and environment is significantly higher than that of social ecological development, resulting in the decline of system coordination. This shows that in recent years, Shangluo has blindly developed economy and developed characteristic tourism, but failed to deal with the associated social problems, such as low urbanization level and low per capita income of farmers[5], urban construction ignores social harmony.

The indicators included in the second principal component (F2) include GDP growth rate, general budget revenue growth rate and the proportion of tourism added value in GDP. Compared with the first component indicators, the correlation degree of these indicators is relatively low, but the impact on economic development cannot be ignored. As the evaluation value reflecting the economic development trend, it is necessary to evaluate the economic subsystem of building an ecological city as the measurement value of the second component. Therefore, the second principal component can be named "economic development potential" index[1].

Economy is regarded as the "hard power" of the development of a city, region and even a country. Its development level will directly determine all aspects of social development. Therefore, while building an ecological city, we should coordinate the basic indicators and potential influence indicators that affect economic development, so as to provide a better development foundation and driving force for the construction of an ecological
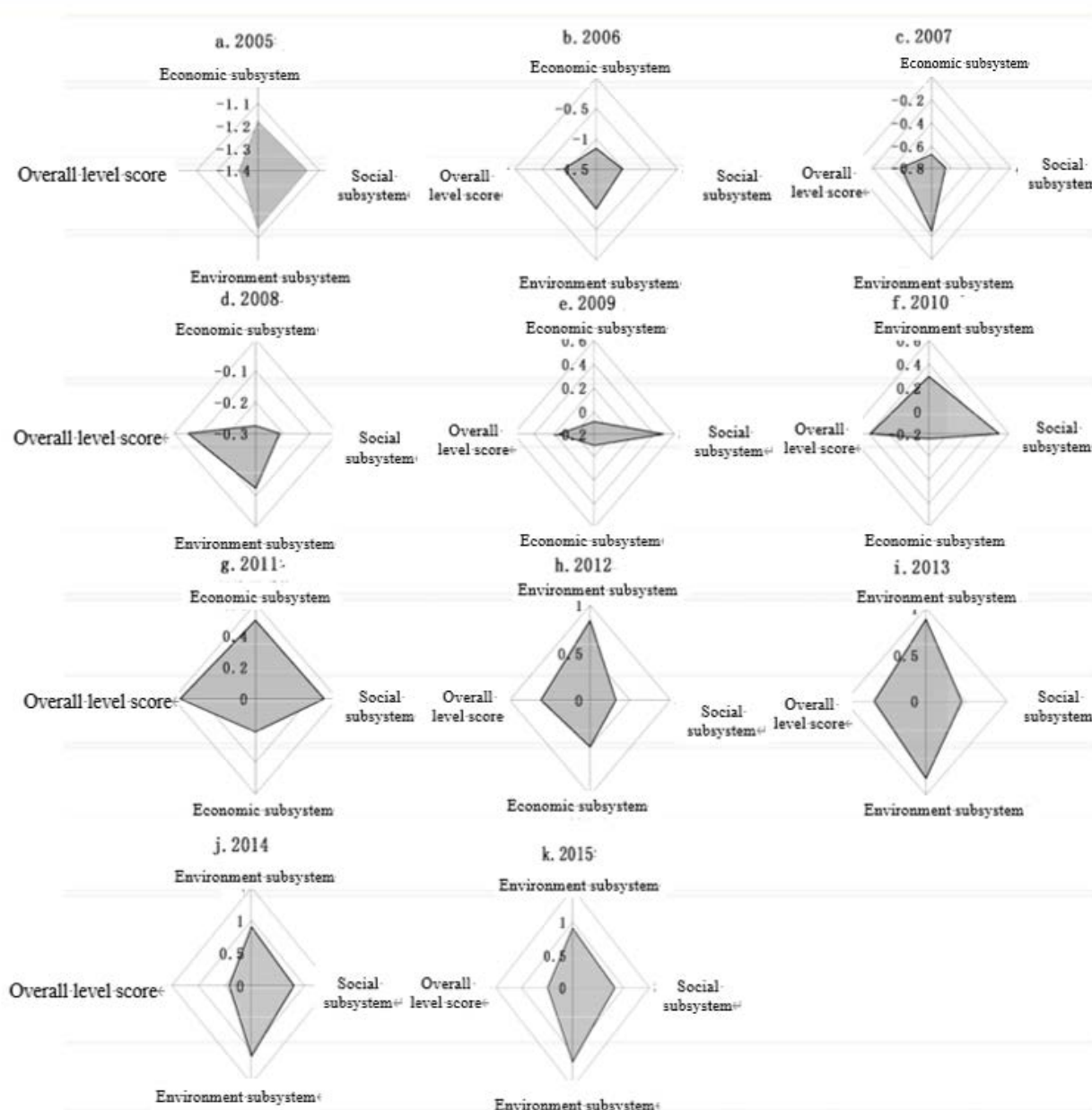
city[14].

Figure 3. The coordination degree of changes of eco-city construction during 2005–2015 in Shangluo.

4.3. Influencing factors

Analysis in principal component analysis, factor load is the correlation coefficient between variable and principal component; for a variable, the greater the absolute value of the load, the closer the relationship between the factor and the principal component. The variance contribution rate is the weight of the principal component. Generally speaking, the variance contribution rate of the first principal component is the largest. Therefore, when analyzing the influencing factors, the indicators with a large degree of correlation with the first principal component are the main influencing factors[4,12].

Factors affecting the ecological construction level of economic subsystem

Through the principal component analysis of the economic subsystem (**Table 1**), it is concluded

that among the 12 indicator layers, the indicators with high correlation with the first principal component (F1) are the per capita disposable income of urban residents, the per capita net income of rural residents, the per capita GDP, the general fiscal budget income and the proportion of fixed asset investment in GDP. The correlation between these indicators and F1 is more than 75%, and they are important indicators to measure the level of eco-

nomic development, It mainly reflects the overall level of economic development. In F1, especially the correlation of per capita disposable income of urban residents, per capita net income of rural residents, per capita GDP and general fiscal budget income is as high as more than 97%, indicating that these indicators have a greater impact on Shangluo's economic development level, so it can be called "economic development level" factor.

Table 1. Rotational component matrix for economic sub-system eco-construction evaluation

Indicator name	Ingredients	
	F1	F2
Per capita GDP	0.987	-0.060
General budget revenue	0.974	-0.161
Per capita disposable income of urban residents	0. 994	0. 008
Per capita net income of rural residents	0. 994	-0.039
Gdp energy intensity	-0.963	-0.033
Power consumption per unit GDP	-0.800	0.524
Proportion of tertiary industry in GDP	-0.987	-0.067
Proportion of fixed asset investment in GDP	0. 815	0. 362
Proportion of tourism value added in GDP	0. 616	0. 643
GDP growth rate	0. 176	0. 933
General budget revenue growth rate	-0.487	0. 736
Growth rate of fixed assets	-0.577	-0.140

Influencing factors of ecological construction level of social subsystem

Through the principal component analysis of 15 indicators of the social subsystem (**Table 2**), the indicators with high correlation with the first principal component (F1) are the per capita insurance premium, the number of college students, the level of urbanization, health technicians and the number of hospital beds from high to low. The correlation between these indicators and F1 is more than 90%, it shows that the first principal component mainly reflects the achievements in urban function construction, social security, education, medical treatment and other infrastructure. The above indicators with high correlation in the first principal component are the main factors affecting the development of social ecology. The development of social subsystem ecology in Shangluo City depends on the above indicators that are constantly optimized. The continuous upgrading of social ecosys-

tem is bound to be conducive to the overall construction of Shangluo ecological city.

The indicators with high correlation with the second principal component (F2) are urban Engel coefficient and rural Engel coefficient, urban road area per capita and other indicators from high to low, which mainly reflect the people's quality of life and urban social security level in Shangluo area. As a supplement to the first principal component, their development degree is also an important factor affecting social ecology.

The third principal component (F3) is mainly the indicators of permanent population, per capita domestic water consumption and the number of authorized patents. Among them, the development of population has a great impact on economic, social and ecological development. A larger population can provide sufficient labor force and consumer market for regional development. However, exces-

sive population will also exert great pressure on resources and environmental protection. Therefore, the third principal component can be interpreted as the influencing factors of population quality and quantity on the construction of Shangluo ecological city.

Table 2. Rotational component matrix for social subsystem eco-construction evaluation

Indicator name	Ingredients		
	F1	F2	F3
Resident population	-0.768	0. 209	0.453
Natural population growth rate	-0.175	0. 254	-0.878
Urbanization level	0.982	-0.088	-0.077
Urban Engel coefficient	0.209	0. 919	0. 267
Rural Engel coefficient	0. 575	0. 798	-0.038
Total construction area of existing housing per capita of urban residents	0. 889	-0.282	-0.043
Per capita domestic water consumption	-0.851	0. 269	0. 350
Number of hospital beds	0. 955	-0.273	0. 039
Urban Road area per capita	0. 561	0. 797	-0.052
Hygienic personnel	0.974	-0.132	0. 015
The registered urban unemployment rate	- 0. 867	-0.377	0. 060
Per capita premium	0. 989	-0.085	0. 057
Number of various safety accidents	- 0. 850	-0.250	-0.279
Number of College Students	0. 985	0. 014	0. 045
Number of authorized patents	0. 754	-0.541	0. 348

Factors affecting the ecological construction level of environmental subsystem

The principal component analysis (**Table 3**) of the environmental subsystem shows that the indicators with high correlation with the first principal component (F1) are the disposal capacity of waste gas treatment facilities, urban per capita park green area, industrial wastewater discharge, comprehensive disposal of industrial solid waste, industrial solid waste discharge, etc. From high to low. The correlation between these indicators and F1 is more than 75%, it can be seen that the first principal component mainly represents the treatment level of industrial three wastes and the level of environmental quality. Therefore, in the later construction of ecological city, the improvement of ecological environment should focus on the treatment of industrial three wastes.

Table 3. Rotational component matrix for environmental subsystem eco-construction evaluation

Indicator name	Ingredients		
	F1	F2	F3
Urban per capita park green space area	0.866	0.413	0.178
Per capita water resources	-0.771	0.575	-0.097
Annual urban air quality compliance rate	-0.416	0.328	0.833
Domestic and other SO_2 emissions	-0.881	-0.131	0.050
Industrial waste gas emission	-0.880	0.291	-0.113
Industrial wastewater discharge	0.846	-0.273	0.026
Urban domestic sewage discharge	0.737	0.299	-0.489
Disposal capacity of waste gas treatment facilities	0.924	0.026	0.144
Discharge of industrial solid waste	0.768	-0.510	0.051
Sewage treatment rate	0.427	0.857	0.089
Utilization rate of industrial solid waste	0.004	0.784	-0.333
Comprehensive disposal volume of industrial solid waste	0.805	0.461	0.238

The indicators with high correlation with the second principal component (F2) are sewage treatment rate, utilization rate of industrial solid waste, per capita water resources, etc. From high to low. These indicators have great correlation with water resources. Therefore, the second principal component can be named water environment quality factor[1].

The indicators with high correlation with the third principal component (F3) are the annual urban air quality compliance rate, which mainly reflects the weather conditions after urban environmental treatment. Through practice, it is found that while optimizing the main indicators involved in the first principal component, we should also take into account the second. Third, these indicators with high correlation in principal components can improve the overall level of ecological environment.

5. Conclusions

Through the empirical analysis of the construction level of ecological city in Shangluo City, it is concluded that the construction of ecological city in Shangluo presents a differentiation trend, the development of economic and environmental construction is good, but the development of social construction is slow, and the coordinated development of economy, society and environment can not be achieved. A good ecological environment plays a vital role in the sustainable development of Shangluo. The coordination and unification of ecological environment, economy and social development in the future is the core goal of building Shangluo ecological city, the foundation of building Shangluo into the most beautiful landscape city in Western China, and an important link to promote the sound and rapid development of Shangluo economy.

Therefore, Shangluo needs to further improve its own comprehensive economic strength and learn from other regions. Give full play to Shangluo's superior environmental conditions, high-quality air and excellent water quality conditions, make use of its rich tourism resources, medicinal materials re-sources, non-ferrous metals and other advantages, reasonably develop and utilize resources, and vigorously develop green and circular economy. The construction of ecological city cannot be achieved overnight. The healthy and sustainable development of economy and society must be based on the sustainable development of environment. The sustainability and stability of economic and social development speed must also depend on the sustainable production capacity, so as to better promote the healthy development of regional ecosystem. At the same time, the government should actively encourage scientific and technological innovation, build an eco city transportation system, and speed up the construction of circular economy industrial organization system, laws and policies, so that the construction of eco city can be carried out well and quickly.

Conflict of interest

The authors declare no conflict of interest.

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