Research Article

Construction of Evaluation Model for Transformation and Development of Rural Areas in Energy-Enriched Poverty-Stricken Areas

Bo Liang

1 College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100000, China
2 Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100000, China
3 Shenzhen Middle School, Shenzhen 518000, China

Correspondence should be addressed to Bo Liang; liangb.17b@igsnrr.ac.cn

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Because of the particularity of energy being non-renewable, the development of energy-intensive cities must consider its follow-up development issues in advance, especially for newly developed energy-intensive cities like Songyuan in the midwest of Jilin Province. It is necessary to summarize the experience from other energy-intensive cities and recognize the problems existing in its own development, so that the development of the city will not perish due to the exhaustion of energy. At present, the sustainable development of energy-intensive cities is the focus of attention at home and abroad. Energy-intensive cities have made great contributions to the national and regional economy but also paid a considerable price. Making the city continue to prosper and develop steadily without causing the city to decline due to the exhaustion of energy is the main problem facing the country, the government, and experts and scholars. Taking Songyuan City in Northeast China as an example, this paper adopts a combination of breakthroughs from the surface and breakthroughs, supplemented by theoretical analysis and empirical evaluation, and uses mathematical model simulation and expert consultation and decision-making methods. Starting from the theoretical height of man-land harmony and sustainable development, we construct an evaluation model of rural development status in energy-enriched poverty-stricken areas, evaluate the evolution trend of rural development status, and propose leading models and development strategies for rural transformation and development in energy-enriched poverty-stricken areas. It provides theoretical reference and decision-making basis for the sustainable development of rural Songyuan City.

1. Introduction

Throughout the development process of energy-intensive cities, energy-intensive cities in any country or region have to go through a process from prosperity to decline. Cities prosper due to the enrichment of energy but also decline due to the depletion of energy, and some cities even go into decline in the process. Energy-intensive cities have made great contributions to national and regional economic development but also brought a series of serious problems to their own development [1]. Most of the energy-intensive cities are generally faced with problems that seriously restrict the sustainable development of energy-intensive cities, such as single urban economic structure, single talent structure and low quality, imperfect system, and poor urban ecological environment. Once the energy-intensive society is on the decline, countries and regions will face not only the survival of the people but also the stability of the society. If a country or region wants to achieve long-term and rapid development, stability is a prerequisite. Therefore, the transformation of energy-intensive cities is particularly important [2–4]. We should not only make effective use of the built urban facilities, but also be responsible to the people of a city and region. Energy-intensive cities refer to cities with a high concentration of energy. An energy-intensive city is a historically prosperous city that drives the entire urban economy through the development of abundant mineral energy in the process of human social and economic
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development. Its pillar industries and leading industries are mainly around the mining of mineral energy and related industries, which are non-renewable. For example, Ruhr in Germany, Lorraine in France, and Northeast China are all energy-rich areas. Often these cities are faced with the problem of how to achieve sustainable urban development and how to transform them when energy is exhausted. Since the 1960s, foreign scholars have studied this issue from different angles [5–7]. Earlier studies on the transformation of energy-intensive cities abroad have provided more references for our research on this aspect. Summarizing foreign theoretical and practical research on the transformation of energy-intensive cities is of great significance for accelerating the transformation of energy-intensive cities in our country and achieving sustainable urban development.

The research on the transformation of energy-intensive cities by experts and scholars in China is also carried out along with the development of the country’s economy and cities. In addition to focusing on the development of energy-intensive cities, the research direction is the macroeconomic system and policies of importing countries [8–10]. It mainly went through the following three stages. In the first stage, from the founding of New China to before the reform and opening up (1949–1978), the research focus was mainly on the balance of regional division of labor and layout. Research at this stage was limited to issues such as site selection and layout, development scale, and construction period. The transformation of energy-intensive cities has not been involved, and the thinking of the entire country and region has not taken into account the subsequent development of energy-intensive cities. The second stage is the period of rapid economic development after the reform and opening up (1978–mid 20th century). As the country’s overall strategy has shifted from a planned economy to a market economy, along with the great social and economic development, energy-intensive cities have also begun to expose some problems. The main problems include backward technology, slow economic growth, declining economic efficiency, rising unemployment, and so on. Many scholars focus on the development of coal cities and the adjustment of industrial structure in energy-intensive cities. The third stage, from the late 1990s to the early 2000s, is mainly the research stage of transformation and sustainable development. With the in-depth development of research on energy-intensive cities, most energy-intensive cities face the problem of energy exhaustion and how to develop cities. How to solve this fundamental problem has become the focus of current scholars’ research [11–13].

Songyuan is a prefecture-level city under the jurisdiction of Jilin Province. It is located in the central and western parts of Jilin Province, in the triangle area of Harbin, Changchun, and Daqing. It borders Baicheng City in the west and Tongliao City in Inner Mongolia and faces Daqing City in Heilongjiang Province across the Songhua River in the north. Together with Baotou, Hohhot, and Ordos, it is known as the “Four Little Dragons of Economic Growth in Northern China.” The mineral resources of Songyuan include petroleum, sand and gravel, quartz sand, glass sand, refractory soil, and nitrate. The oil reserves are 1.08 billion tons, the natural gas reserves are 18.5 billion cubic meters, and the oil shale reserves are 8 billion tons [14–16]. The sixth largest onshore oil field in China, Jilin Oilfield, is located in Songyuan. In 2004, the crude oil output reached 5.05 million tons.

Through a systematic study of rural development and construction models in energy-enriched poverty-stricken areas taking Songyuan City as an example, this paper discusses the process and mechanisms of rural village transformation and development and provides a framework for geographic research on rural development in energy-enriched areas [17–19]. This new way of thinking will help enrich the research content of the regional geography and rural geography in China.

2. Methods and Theory

2.1. Selection of Evaluation Methods. In view of the fact that rural development involves many factors such as economy, ecological environment, and rural life and the interactions are intricate, the identification of dominant factors and the reasonable adjustment of dominant factors are of great significance for the sustainable development of regional rural areas and the benign changes in the ecological environment. Here, the principal component analysis method is used to identify the main factors of Songyuan’s rural economic strength, regional ecological environment quality, and resource carrying capacity, and through the coupling analysis of the three, the state of rural transformation and development in the region is evaluated. Principal component analysis eliminates the interaction between indicators through data dimensionality reduction and displays the effect of each main influencing factor in the form of a loading matrix. In addition, the weight used in the comprehensive evaluation of multiple indicators by the principal component analysis method belongs to the weight of information, and the importance of the indicator is determined by the amount of information contained in the indicator to distinguish the samples, which is generated by mathematical transformation and is subject to subjective human factors. The impact is small, which helps to objectively reflect the real relationship between samples and can improve the effectiveness of comprehensive evaluation. The main steps are as follows.

Step 1. The data are dimensionless, and the original data matrix of n samples and p indicators is $X = \{x_{ij}\}_{n \times p}, i = 1, 2, \ldots, n$ means n samples, $j = 1, 2, \ldots, p$ means p indicators, and let

$$X' = (X'_1, X'_2, \ldots, X'_m) = [x_{ij}]_{n \times m},$$

(1)

where

$$x'_{ij} = \frac{x_{ij} - \bar{x}_j}{\sigma_j},$$

$$\bar{x}_j = \frac{1}{n} \sum_{i=1}^{n} x_{ij},$$

$$\sigma_j^2 = \frac{1}{n-1} \sum_{i=1}^{n} \frac{x_{ij} - \bar{x}_j^2}{(n - 1)}.$$

(2)
Step 2. Calculate the correlation coefficient matrix $R$:

$$r_{ij} = \frac{1}{N} \sum_{k=1}^{n} \frac{(x_{kj} - \bar{x}_j)(x_{ki} - \bar{x}_i)}{\sigma_k \sigma_j}.$$  \hfill (3)

Step 3. Calculate eigenvalues and eigenvectors. According to the characteristic equation $|R - \lambda I| = 0$, calculate the eigenvalues $\lambda_i$ $(i = 1, 2, \ldots, p)$, and arrange them in order of magnitude.

The eigenvectors $\mathbf{l}_i$ corresponding to the eigenvalues $\lambda_i$ are obtained, respectively.

Step 4. Calculate the principal component contribution rate and cumulative contribution rate. The variance contribution rate of the principal component $Z_k$ is $\lambda_k/\sum_{i=1}^{p} \lambda_i$, and the cumulative contribution rate of the first $m$ principal components is $\sum_{i=1}^{m} \lambda_k/\sum_{i=1}^{p} \lambda_i$. Generally, the principal components corresponding to the eigenvalues with a cumulative contribution rate of 85–95% can be taken.

Step 5. Calculate principal component loadings:

$$p(Z_k, x_i) = \sqrt{\frac{\lambda_k}{\lambda_i}}.$$

$$(i = 1, 2, \ldots, p; k = 1, 2, \ldots, m).$$ \hfill (4)

Step 6. Determine the weight $W$:

$$W_m = \frac{\lambda_m}{\sum_{i=1}^{m} \lambda_i}. \hfill (5)$$

Step 8. Calculate the comprehensive evaluation value $F$:

$$F = W_1Z_1 + W_2Z_2 + W_3Z_3 + \cdots + W_mZ_m. \hfill (6)$$

### 3. Results and Discussion

#### 3.1. Analysis of the Economic Strength of Rural Transformation and Development

The strength of rural economic development can be specifically divided into per capita rural social output value (X1), per capita agricultural output value (X2), farmers’ per capita net income (X3), GDP growth rate (X4), fixed asset investment (X5), non-agricultural proportion of population (X6), proportion of output value of secondary and tertiary industries (X7), total power of agricultural machinery (X8), grain yield (X9), per capita sown area (X10), effective irrigation area (X11), average years of education of labor force (X12), per capita consumption expenditure (X13), Engel coefficient (X14), rural per capita housing area (X15), and health technicians (X16). It can be seen from Table 1 that the cumulative contribution rate of principal components X1, X2, and X3 reaches 93.677%, which meets the requirements of principal component analysis. In order to reasonably explain each common factor, the factor loading matrix is orthogonally transformed by using the maximum variance orthogonal rotation method, so as to achieve the clarification of the characterization factors of each principal component. Principal component X1 has 74.531% of all information and is a very important factor. It is a very important factor in the per capita rural social output value, the per capita net income of farmers, the proportion of non-agricultural population in fixed asset investment, the total power of agricultural machinery, the average income and education level of the labor force, and the per capita consumption in rural areas. The total expenditure and health technicians have relatively large loadings, indicating that the principal component X1 is a comprehensive factor that characterizes the agricultural production conditions and the rural economic foundation. Principal component X2 has a great correlation with the per capita housing area in rural areas and is a factor that characterizes the living standards in rural areas. Principal component X3 has a high correlation with GDP growth and is a factor representing the economic foundation. After sorting out and analyzing the above related factors, the factors affecting the rural economic development of Songyuan City can be summarized as three types of factors: agricultural production conditions and rural economic foundation, rural living standards, and rural macroeconomic environment.

On the basis of principal component analysis, according to the comprehensive evaluation function evaluation method established above, the rural economic strength score of Songyuan City can be calculated. The larger the comprehensive evaluation function value, the higher the regional economic development level. Similarly, through the comprehensive evaluation function of each county’s rural
economic strength, the score of each county’s rural development strength is obtained.

Through the above analysis, combined with the principal component score formula of Songyuan City derived from the eigenvectors, the weights \( F_X \) of the three principal components are determined according to the weight formula as

\[
W_X = \begin{bmatrix} 0.8523, 0.1158, 0.0454 \end{bmatrix}.
\]  

Combined with the comprehensive evaluation value

\[
F_X = W_X Z_X = W_X X_1 Z_{X1} + W_X X_2 Z_{X2} + W_X X_3 Z_{X3} + \cdots + W_X X_m Z_{Xm},
\]

the comprehensive score of economic strength of rural development in Songyuan City can be calculated. Figure 1 shows the change trend of the comprehensive evaluation value of Songyuan City from 2008 to 2015.

### 3.2. Eco-Environmental Quality Assessment of Rural Transformation and Development

The quality of living environment can be subdivided into annual average rainfall \( Y_1 \), annual average temperature \( Y_2 \), per capita GDP \( Y_3 \), per capita gross industrial output value \( Y_4 \), per capita net income of farmers \( Y_5 \), Engel coefficient \( Y_6 \), population density \( Y_7 \), proportion of rural practitioners’ ecological environment quality \( Y_8 \), effective irrigated area \( Y_9 \), the proportion of grain crop area to total crop area \( Y_{10} \), the amount of fertilizer application \( Y_{11} \), the amount of agricultural film application \( Y_2 \), pesticide consumption \( Y_{13} \), industrial wastewater discharge \( Y_{14} \), industrial waste gas discharge \( Y_{15} \), industrial solid waste discharge \( Y_{16} \), and comprehensive utilization of three wastes \( Y_{17} \). It can be seen from Table 2 that the cumulative contribution rate of the principal components \( Y_1, Y_2, Y_3, \) and \( Y_4 \) reaches 85.851%, which met the requirements of principal component analysis. The first four factors are extracted as the public factors for the evaluation of the rural ecological environment quality in Songyuan City. In order to reasonably explain each public factor, the factor loading matrix is orthogonally rotated by the maximum variance orthogonal rotation method, so as to clarify the characterization factors of each principal component. The principal component \( Y_1 \) has 52.023% of all the information, which is a very important factor. Income, per capita GDP, per capita industrial output value, Engel coefficient, and comprehensive utilization of the three wastes have relatively large loads, indicating that the principal component \( Y_1 \) is a comprehensive factor representing the ecological pressure of economic activities. Principal component \( Y_2 \) has a large load on the three indicators of pesticide dosage, industrial waste gas emission, and agricultural film application amount. According to the following principal component \( Y_3 \), which characterizes the ecological pressure of industrial production, the industrial waste gas emission is kicked out, indicating that the principal component \( Y_2 \) is the factor that characterizes the ecological pressure of agricultural activities. Principal component \( Y_3 \) has a high correlation with industrial solid waste emissions and is a factor that characterizes the ecological pressure of industrial production. Principal component \( Y_4 \) has a high correlation with the proportion of rural employees, but rural employees mainly refer to the labor force engaged in agriculture and related industries, and the aforementioned ecological pressure factors of agricultural activities belong to the category of agricultural economic activities, so they are classified into one category. The above related factors are comprehensively analyzed, and the factors affecting the ecological environment of Songyuan City are summarized into three types of factors: the comprehensive factor of economic activity ecological pressure, the ecological pressure factor of agricultural activity, and the ecological pressure factor of industrial production. It is not difficult to see that the main factors affecting the ecological environment of Songyuan City involve agricultural production and industrial activities, which confirms the non-point source pollution of soil caused by pesticides and fertilizers in local rural production, as well as the environmental impact of rural residents’ activities such as grazing and digging for licorice. At the same time, ecological problems such as land degradation and ground subsidence caused by the development of energy resources have become increasingly prominent. On the basis of principal component analysis, according to the comprehensive evaluation function evaluation method established above, the scoring equations of each principal component are constructed to comprehensively evaluate the evolution trend of rural ecological environment quality in Songyuan City. Through the above analysis, the principal components of the ecological environment quality of Songyuan City derived from the eigenvectors can be obtained. According to the weight formula, \( F_Y \) of the four principal components can be obtained as

\[
W_Y = \begin{bmatrix} 0.5936, 0.1698, 0.1235, 0.1131 \end{bmatrix}.
\]  

Combined with the comprehensive evaluation value

\[
F_Y = W_Y Z_Y = W_Y Y_{11} Z_{Y1} + W_Y Y_{12} Z_{Y2} + W_Y Y_{13} Z_{Y3} + \cdots + W_Y Y_{ym} Z_{Ym},
\]

the comprehensive score of the ecological environment quality of the rural transformation and development of Songyuan City can be calculated. Figure 2 shows the change trend of

| Characteristic root and contribution rate | Eigenvalues   | Contribution rate | Cumulative contribution rate |
|------------------------------------------|---------------|-------------------|-----------------------------|
| X1                                       | 10.932        | 74.531            | 74.531                      |
| X2                                       | 1.546         | 11.21             | 85.741                      |
| X3                                       | 1.203         | 7.936             | 93.677                      |
| X4                                       | 0.513         | 3.256             | 96.933                      |
| X5                                       | 0.423         | 1.023             | 97.956                      |
| X6                                       | 0.092         | 0.5917            | 98.5477                     |
| X7                                       | 0.065         | 0.568             | 99.1157                     |
| X8                                       | 0.054         | 0.455             | 99.5707                     |
| X9                                       | 0.034         | 0.232             | 99.8027                     |
| X10                                      | 0.025         | 0.115             | 99.9177                     |
| X11                                      | 0.013         | 0.047             | 99.9647                     |
| X12                                      | 0.0035        | 0.035             | 99.9997                     |
| X13                                      | 0.0004        | 0.0001            | 99.9998                     |
| X14                                      | 0             | 0.0002            | 100                         |
| X15                                      | 0             | 0                 | 100                         |
| X16                                      | 0             | 0                 | 100                         |

Table 1: Characteristic roots of rural economic strength factors.
the comprehensive evaluation value of Songyuan City from 2008 to 2015.

3.3. Analysis of Resource Carrying Capacity of Rural Transformation and Development. Resource carrying capacity can be divided into average rainfall (V1), average annual temperature (V2), arable land area (V3), per capita grain yield (V4), population density (V5), natural population growth rate (V6), farmland water conservancy management area (V7), and soil and water conservation forest area (V8). It can be seen from Table 3 that the cumulative contribution rate of principal components V1, V2, V3, and V4 reaches 93.053%, and the first four factors are extracted as the public factors of the rural resource carrying capacity of Songyuan City. The factor loading matrix is orthogonally rotated by the maximum variance orthogonal rotation method, so that the principal component characterization factors are clarified. Principal component I has 50.231% of the information, which is a relatively important factor. It has a large load in the two indicators of population density and farmland water conservancy management area, indicating that principal component V1 is an index factor that characterizes population carrying capacity. Principal component V2 has a high correlation with per capita grain yield and is an index factor to characterize grain carrying capacity. Principal component V3 has a high load on annual rainfall and is a factor to characterize water resources carrying capacity. Principal component V4 is related to soil and water. Maintaining the forest area has a strong correlation and is an indicator factor to characterize the ecological carrying capacity. The above related factors are sorted out and analyzed, and the influencing factors of the resource carrying capacity of the study area are summarized as four types of factors: population carrying capacity, food carrying capacity, water resources carrying capacity, and ecological carrying capacity.

On the basis of principal component analysis, according to the comprehensive evaluation function evaluation method established above, the scoring equation of each principal component is constructed to comprehensively evaluate the evolution trend of rural resource carrying capacity in Songyuan City. Through the above analysis, the principal components of the resource carrying capacity of Songyuan City derived from the eigenvectors are calculated. According to the steps in the evaluation method, the weights \( W_V \) of the four principal components are determined as

\[
W_V = [0.5036, 0.2452, 0.1139, 0.0973].
\]  

Combined with the comprehensive evaluation value

\[
F_V = W_{V1}Z_{V1} + W_{V2}Z_{V2} + W_{V3}Z_{V3} \cdots + W_{Vm}Z_{Vm},
\]

the comprehensive score of the ecological environment quality of the rural transformation and development of Songyuan City can be calculated. Figure 3 shows the change trend of

![Figure 1](https://example.com/figure1.png)

**Figure 1:** The change trend of the comprehensive evaluation value of Songyuan City from 2008 to 2015 (economy).

| Characteristic root and contribution rate | Eigenvalues | Contribution rate | Cumulative contribution rate |
|-----------------------------------------|------------|------------------|-----------------------------|
| Y1                                      | 8.961      | 52.034           | 52.034                      |
| Y2                                      | 2.672      | 16.756           | 68.79                       |
| Y3                                      | 1.854      | 11.365           | 80.155                      |
| Y4                                      | 1.563      | 5.696            | 85.851                      |
| Y5                                      | 1.023      | 4.732            | 90.583                      |
| Y6                                      | 0.6432     | 3.563            | 94.146                      |
| Y7                                      | 0.3564     | 2.3843           | 96.5303                     |
| Y8                                      | 0.2305     | 1.569            | 98.0993                     |
| Y9                                      | 0.1459     | 0.8632           | 98.9625                     |
| Y10                                     | 0.0432     | 0.4589           | 99.4214                     |
| Y11                                     | 0.0201     | 0.3263           | 99.7477                     |
| Y12                                     | 0.0125     | 0.1683           | 99.916                      |
| Y13                                     | 0.0026     | 0.078            | 99.994                      |
| Y14                                     | 0.0001     | 0.006            | 100                         |
| Y15                                     | 0          | 0                | 100                         |
| Y16                                     | 0          | 0                | 100                         |
| Y17                                     | 0          | 0                | 100                         |
the comprehensive evaluation value of Songyuan City from 2008 to 2015.

3.4. Coupling Evaluation of Rural Transformation and Development Status. Based on the evaluation results of Songyuan City’s ecological environment quality, rural economic strength, and resource carrying capacity, the evaluation method of the three-system state coupling is used to evaluate the rural development status of Songyuan City, and the rural development status is divided into sustainable development, moderate sustainable development, and impossible development. There are three states of sustainable development. If a region has an upward trend in rural economic strength,
ecological environment quality, and resource carrying capacity within a certain period, then the region is in a state of sustainable development. If only two of them show a growth trend, then the region is in a state of moderate sustainable development. The region where only one indicator rises and the others decline is in an unsustainable state of development. According to the analysis results of the economic strength, ecological environment quality, and resource carrying capacity of the rural transformation and development of Songyuan City, the ecological environment quality of the city has been in a deteriorating trend, while the rural economic strength and resource carrying capacity have shown a steady upward trend.

4. Conclusion

(1) Using the factor analysis method, this paper analyzes the economy, ecological environment quality, and resource carrying capacity of Songyuan City. The results show that the ecological environment quality of the city has been in a worsening trend, while the rural economic strength and resource carrying capacity have shown a steady upward trend.

(2) The development of Songyuan City must obtain ecological benefits while obtaining economic benefits. If there is no economic benefit, no matter how high the ecological benefit is, it will be difficult to last because the environmental governance cannot be supported by the masses. Conversely, if the local ecological benefits decline year by year, it will affect rural production and life, and rural income will decline. In addition, the increase in medical and healthcare costs caused by environmental pollution will indirectly reduce farmers’ income. Therefore, ecological construction must pay attention to long-term benefits while paying attention to short-term benefits, so as to achieve a win-win situation between ecology and economy.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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