Evaluation Research on the Impacts of Coal Industry Development on Ecological Security in Inner Mongolia

Li Li¹, ², a, Jiabin Chen³, b, Dan Yan⁴, *
¹State Key Laboratory of Water Resource Protection and Utilization in Coal Mining, Beijing, 100011, China
²School of Economics and Management, China University of Geosciences, Beijing, 100083, China
³China Academy of Natural Resources Economics, Beijing, 101149, China
⁴Tsinghua-Berkeley Shenzhen Institute, Shenzhen, 518071, China

Corresponding author e-mail: yandan1718@163.com, a lilyght@126.com, b myroom308@126.com

Abstract. The paper uses PSR model to evaluate the ecological security situation from three dimensions of stress, state and response. The results show the level of economic development, social harmony and the realization of low-carbon ecological integrated Systems in Inner Mongolia is -0.03373, 0.053565, and 0.117664. The development degree, development continuity, development coordination degree and development effectiveness of low carbon ecological area construction in Inner Mongolia are 0.13361, 1.656154, 57.98879, 0.01741. The evaluation result of the sustainability of low carbon ecological development in Inner Mongolia is in the fourth level. The degree of development coordination and development effectiveness are judged at level five. Through the evaluation and grading results of low carbon ecological development in Inner Mongolia, we know that Inner Mongolia, as a coal resource-based region, is under great pressure to develop low-carbon ecology.

1. Introduction
Coal industry refers to the composite industrial system for the purpose of developing and utilizing coal, including coal resources exploration, mining, washing, processing, warehousing, logistics, sales, utilization, as well as other coal-related scientific research, training, testing and other activities of enterprises and institutions collectively, covering the upstream, midstream and downstream industrial sectors. In a narrow sense, the coal industry only refers to the coal mining and washing industry in the National Economic Industry Classification table, that is, engaged in anthracite, bituminous coal, lignite and other raw coal species mining, washing and grading of the production activities of enterprises and undertakings, including underground or ground mining, mine operation, And all ancillary works aimed at adding raw materials, such as milling, mineral processing and treatment, which are generally carried out on or near mine sites, but do not include the production of coal products, coal exploration and construction activities.

As a resource-intensive industry, the coal industry, under the traditional exploration and development mode, mainly takes extensive exploration and opening, and basically does not take into account such
factors as environmental cost, ecological cost and residents' health, and the result of its development will inevitably bring far-reaching negative effects on ecological environment and human health. More and more regions are facing the dilemma of depletion of resources, weak growth and a sharp deterioration of the ecological environment, which seriously restricts the sustainable development of the local economy and even the Chinese economy. The establishment of a model that can assess the impact of coal industry on ecological security can effectively control the damage of coal industry to the environment and accelerate the transformation of the sustainable development of coal industry.

"Ecological security" is born with the increasing impact of economic and social development on the human natural environment. Before the industrial Revolution, the population was small, the level of human production technology was relatively low, and the natural environment was not deeply affected by the degree of negative intervention and impact. Because everything is still within the scope of the natural environment can be carried, so the ecological environment for human waste can be self-internal disposal, the destruction of the natural ecological environment can also repair themselves. However, after the industrial Revolution, the development of industry and the progress of science and technology reflected the great demand and consumption of resources by mankind at an unprecedented cost. In particular, after the second industrial Revolution, the population of the entire planet grew dramatically [1]. The increase in population means a greater demand for resources, while countries have to seize the opportunity to develop their economies, so the demands on natural resources have reached unprecedented intensity. With the further development of society, the demand of human beings become more, and the quality of demand become higher, which further increases the burden of ecology. Constant demand, the negative impact on the ecology will continue to increase. Mankind obtains from nature all kinds of resources needed for human development, but at the same time, human beings have a great negative impact on the natural environment, the living environment is deteriorating, seriously affecting the long-term economic and social development, and even endangering the property security of human life. Therefore, the concept of ecological security is not originally there, but is produced with the development of human society. It embodies that human beings in production, life and health are not affected by ecological damage and environmental pollution and other aspects of the impact and constraints, and it covers not only the air, water, natural environment, but also includes some basic elements of food safety. Ecological security reflects a stable ecosystem state, where "stability" is reflected in its autonomy on the one hand, and negative immunity from external interference [2]. On the contrary, ecological insecurity characterizes the ecosystem in which functions are affected and is in a threatened state. Ecological environment is the cradle of life on Earth and the foundation of social development and economic progress in a country or region. Ecological security, is to express the human survival is not threatened, social development can be sustainable a state, it has become a major issue related to the national economy and People's livelihood, to a certain extent has become a measure of the level of security of a country or region an important indicator[3].

Inner Mongolia Autonomous Region is the province with the most coal in China. The total estimated resources of coal in the region are 851.88 billion tons, of which the resource reserves identified are 422.08 billion tons and the projected resource volume is 429.8 billion tons. The region has 411.065 billion tons of coal reserves, accounting for 26.24% of the country's total, ranking first in the country. As a typical coal resource-based region, Inner Mongolia faces the dual pressures of industrial transformation and upgrading and environmental protection. Therefore, this paper evaluates the impact of the development of Inner Mongolia's coal industry on ecological security.

2. Construction of the model
The paper uses PSR model, which is the United Nations Economic Cooperation and Development Agency (OECD) based on the relationship between people and the environment, and proposesto evaluate the ecological security situation from three dimensions of stress, state and response [4]. The PSR model is based on the basic theory that human social and economic activities are not independent and interrelated with the natural environment in which human beings live, that they are not individuals who exist alone, and that the natural environment provides all kinds of matter and energy for the survival and
development of human beings. Human beings, through production and consumption, have discharged metabolites and waste into the natural environment, human production and consumption activities, resulting in lower reserves of resources, production and life of waste, but also on the environmental quality of the impact. The ecosystem is disturbed by external forces and poses a threat to human survival and life. In order to alleviate the deterioration of ecological conditions, human beings take certain measures, such a cycle, the formation of a "pressure-state-response" such a relationship. The PSR index system is constructed on this basis, which has a clear causality, and the pressure layer index mainly reflects which human activities will bring damage to the natural ecological environment and bring pressure to the ecology, and when human activities have a "pressure" effect on the natural environment, that is, it has a negative impact, Then the state of the ecosystem has changed to a certain extent, then the state index is to reflect the ecological state after the pressure, that is, the impact of "pressure"; the response index reflects what measures human beings have taken in the face of negative effects to eliminate and mitigate, prevent its further deterioration, and improve its ecological status. On the basis of the PSR model, the DPSR model, namely the driving force-pressure-state-RESPONSE model and the DPSIR model, which is the driving force-pressure-shape state-impact-response model, is also derived.

2.1. Construction of the evaluation model

(1) The Three-level evaluation index of low carbon ecological development in coal resource-based areas refers to the realization of the current value of the basic index relative to the target value in the year of regional development evaluation. The calculation method is shown in formula (1):

\[ GI_{ij} = \frac{C_{ij} - S_{ij}}{G_{ij} - S_{ij}} \]  (1)

Formula (1) i represents the level II indicator ordinal, j represents the level III indicator ordinal; \( S_{ij} \) represents the starting value of the basic evaluation Index, and \( G_{ij} \) represents the target value of the basic evaluation index; \( C_{ij} \) The present value of the basic evaluation index is expressed, and the \( GI_{ij} \) represents the realization level of the individual index construction.

(2) The Comprehensive evaluation Index of low carbon ecological development in coal resource-based areas includes: the level of development and achievement of comprehensive system, the degree of development effectiveness, the development continuity and the coordination degree of development. The development level of integrated system refers to the Comprehensive Development level evaluation of coal resource-based regional economic development, social harmony and low carbon ecology at a specific time. In this paper, analytic hierarchy process is used to calculate the development level of integrated system. The calculation method is shown in formula (2):

\[ CGI_{i} = \sum \omega_{ij} GI_{ij} \]  (2)

Formula (2), \( \omega_{ij} \) represents the weight of the individual EVALUATION index, \( CGI_{i} \) represents the development level of the integrated system, and the other parameters mean the same formula (1). In this paper, the spatial vector method is used to calculate the development, coordination degree, development continuity and development effectiveness of low carbon ecological development in coal resource-based areas. The degree of development realization refers to the realization degree of the existing low carbon ecology in the coal resource type area compared with the final low carbon ecological construction target in the region, and the development effectiveness refers to the measurement of the effectiveness of the relative construction goal of the low Carbon Ecological PSR index in the Coal resource type area. The development continuity refers to the PSR index of the coal resource type area. The measurement of social harmony and the sustainable development of low carbon ecological system; the degree of
Development coordination refers to the measurement of the optimal path fitting degree of low carbon ecological development in coal resource-based areas. The calculation methods are as follows:

\[
GD = \sqrt{(CC_1 I_1)^2 + (CGI_2)^2 + (CGI_3)^2}
\]

\[
GS = \sqrt{(1 - CC_1 I_1)^2 + (1 - CGI_2)^2 + (1 - CGI_3)^2}
\]

\[
GC = \arccos \left( 3 + \arccos \frac{3GD^2 - GS^2}{2\sqrt{3 - GD}} \right)
\]

\[
GV = GD \times \cos GC
\]

Formula (3), GD indicates the realization degree of regional low carbon ecological development; in formula (4), GS indicates the sustainability of regional low-carbon ecological development; in formula (5), GC indicates the coordination degree of regional low carbon ecological development; in formula (6), GV indicates the effective degree of regional low carbon ecological development [5].

2.2. Construction of Evaluation Index System

Based on the principle of PSR model, combined with the low Carbon Regional Evaluation Index system issued by the Chinese Academy of Sciences and the index system of eco-city construction issued by the State Environmental Protection Administration, this paper establishes the system of including pressure index, the basic index system for evaluation of low carbon ecological development in coal resource-based areas of three level two index and 22 three-level index of State index system and Response index system is shown in table 1.

In table 1, pressure (P) refers to the factors that economic development and social demand inevitably cause oppression for regional low-carbon ecological development; State (S) refers to the actual economic, social and ecological data of regional low-carbon ecological development during the specific assessment stage; response (R) refers to the process of low carbon ecological development in the region, Factors that may positively or negatively affect low-carbon ecological transformation in high-carbon regions [6].

2.3. Grading of Evaluation Results

For the single and comprehensive evaluation index of low carbon development of coal resource type area based on PSR Model, it is necessary to classify and rank in order to facilitate the specific assessment, and the grading standard should follow the principles of science, rationality, Systematicness and testability. Flexible adjustments and changes should also be made in accordance with regional construction objectives. This paper studies the evaluation classification criteria of low carbon ecological area construction set [7, 8], and makes scientific adjustment in combination with the goal of low carbon ecological development in coal resource-based areas. The adjusted rating criteria for evaluation results are shown in table 2. Table 2 is the grading standard for the evaluation index of low-carbon ecological development in coal resource-based regions.
Table 1 Basic Evaluation Index data of low carbon economy development in Inner Mongolia

| Level I indicators | Level II indicators | Level III indicators | Start Value (2016) | Status values (2017) | Target value (2020) | Weight |
|--------------------|---------------------|----------------------|--------------------|----------------------|---------------------|--------|
| Economic development | 1. Total gross provincial product (100 million yuan) P | 18128.1 | 16096.21 | 22886.18 | 0.04125 |
| | 2. Local fiscal revenue (10 thousand yuan) P | 20164334 | 17032095 | 34854619 | 0.04125 |
| | 3. Annual per capita gross product (10 thousand yuan /person) P | 7.19 | 6.37 | 8.0 | 0.04125 |
| | 4. Tertiary industry as a share of GDP (%) S | 43.78 | 49.99 | 60 | 0.04125 |
| | 5. Total retail sales of social consumer goods (100 million yuan) R | 6700.76 | 7160.2 | 12919.45 | 0.04125 |
| | 6. Investment in fixed assets in the whole society (100 million yuan) R | 14893.96 | 13827.85 | 18269.13 | 0.04125 |
| | 7. Total imports and exports (10 thousand of United States dollars) R | 1164030 | 1387352 | 1500000 | 0.04125 |
| | 8. Engel coefficient (%) S | 28.4 | 28.3 | 25 | 0.04125 |
| Ecological security level of coal-type region | Social harmony | 1. Urban registration unemployment rate (%) P | 3.65 | 3.63 | 3.5 | 0.047143 |
| | 2. billion Yuan output value production safety accident mortality rate (10 thousand yuan/person) P | 7.48 | 7.89 | 5 | 0.047143 |
| | 3. Level of urbanization (%) S | 61 | 62 | 65 | 0.047143 |
| | 4. Urban and rural residents' income ratio S | 2.84 | 2.83 | 2.7 | 0.047143 |
| | 5. Per capita disposable income of urban residents (yuan) R | 32975 | 35670 | 42000 | 0.047143 |
| | 6. Per capita disposable income of rural residents (yuan) R | 11609 | 12584 | 15000 | 0.047143 |
| | 7. Average number of students per 100,000 population R | 1936.67 | 1969 | 2000 | 0.047143 |
| Low Carbon ecology | 1. Total energy consumption (10 thousand tons of standard coal) P | 19457 | 20566.049 | 20000 | 0.04125 |
| | 2. Water consumption per capita (cubic metre/person) P | 756.5 | 744.7 | 700 | 0.04125 |
| | 3. Urban sewage treatment capacity per day (10 thousand cubic metres) | 245.5 | 248.1 | 260 | 0.04125 |
| | 4. Comprehensive utilization of solid pollutants (10 thousand tons) S | 11359 | 10422 | 13000 | 0.04125 |
| | 5. Forest savings (10 thousand cubic metres) R | 134530.48 | 134530.48 | 140000 | 0.04125 |
| | 6. Number of public transport per million people (standard vehicle) R | 10.26 | 10.65 | 12 | 0.04125 |
| | 7. Energy saving and Environmental protection financial expenditure (10 thousand yuan) R | 1593894 | 1436651 | 130000 | 0.04125 |
| | 8. Coal production (100 million tons) | 8.38 | 8.79 | 9 | 0.04125 |

Source: Wind, Inner Mongolia Statistical Yearbook
Table 2 classification criteria for evaluation of ecological development of coal resources

| Grade | Level I | Level II | Level III | Level IV | Level V |
|-------|---------|----------|-----------|----------|---------|
| GIi   | ≥1      | 0.76~1   | 0.26~0.75 | 0.06~0.25 | ≤0.05   |
| CGIi  | ≥1      | 0.76~1   | 0.26~0.75 | 0.06~0.26 | ≤0.05   |
| GD    | ≥1.73   | 1.31~1.73| 0.45~1.30 | 0.10~0.44 | ≤0.09   |
| GS    | ≤0      | 0.08~0.4 | 0.41~1.28 | 1.29~1.63 | ≥1.64   |
| GC    | ≥3      | 3~13     | 14~41     | 42~51    | ≥52     |
| GV    | ≥1.73   | 1.31~1.73| 0.45~1.30 | 0.10~0.44| ≤0.09   |

| Results | Very high | High | Normal | Low | Very low |

Source: Yuan Yuan [5]

3. Results

An ecosystem is a complex internal structure that involves many factors and contains many levels of systems. The construction of early warning system for regional ecological security is also an important content in the field of regional ecological security research, the design of Early warning index system should take full account of the characteristics of regional ecological security, but also consider the meaning of early warning, it requires that the selection of indicators in the index system can not only reflect the current state of the region's health security situation, It is also necessary to selectThe potential main factors that will affect the development trend of regional ecological security. According to the evaluation early warning model constructed, and the formula (1)-(6), The evaluation results of low carbon ecological development level in Inner Mongolia can be calculated, As shown in table 3.

Table 3 Evaluation results of low carbon ecological development level in Inner Mongolia

| indicators | Results | indicators | Results | indicators | Results | indicators | Results |
|------------|---------|------------|---------|------------|---------|------------|---------|
| GI11       | -0.42704| GI21       | 0.133333| GI31       | 2.042448| CGI1       | -0.03373|
| GI12       | -0.21322| GI22       | -0.16532| GI32       | 0.20885 | CGI2       | 0.053565|
| GI13       | -1.01235| GI23       | 0.000155| GI33       | 0.17931 | CGI3       | 0.117664|
| GI14       | 0.382861| GI24       | -0.071429| GI34      | -0.57099| GD         | 0.13361 |
| GI15       | 0.073881| GI25       | 0.298615| GI35      | 0      | GS         | 1.656154|
| GI16       | -0.31587| GI26       | 0.287526| GI36      | 0.224138| GC         | 57.98879|
| GI17       | 0.664708| GI27       | 0.510501| GI37      | 0.107414| GV         | 0.01741 |
| GI18       | 0.029412| GI28       | 0.66129 |          |         |            |         |

As shown in table 3, the level of economic development, social harmony and the realization of low-carbon ecological integrated Systems in Inner Mongolia is -0.03373, 0.053565, and 0.117664. Through the calculation of Formula 3, 4, 5 and 6, the development degree, development continuity, development coordination degree and development effectiveness of low carbon ecological area construction in Inner Mongolia are 0.13361, 1.656154, 57.98879, 0.01741. According to the five-level evaluation standard of fencing method, the individual and comprehensive evaluation indexes of low carbon ecological development in Inner Mongolia are graded one after another, and we know that 1 of the 22 individual indexes are judged as the first level and 9 are judged as the fifth level; The realization degree of low carbon ecological development in Inner Mongolia is judged as level two, and The evaluation result of the sustainability of low carbon ecological development in Inner Mongolia is level four, The degree of development coordination and development effectiveness are judged at level five.

Through the evaluation and grading results of low carbon ecological development in Inner Mongolia, we know that Inner Mongolia, as a coal resource-based region, is under great pressure to develop low-carbon ecology.
4. Policy recommendations

This paper evaluates the relationship between the development of coal industry and ecological security in Inner Mongolia from 3 aspects of pressure, state and response. The research shows that the overall level of ecological security in this area is not high, in a less ecologically insecure state. In order to maintain the Sustainable development of nature, economy and society in Inner Mongolia and form a stable ecological security pattern, we must scientifically and rationally carry out human economic and social activities, reduce the pressure of resource carrying and environmental pollution, and greatly increase the investment of environmental protection, science and education, health care and public utilities. Thus improving the quality of ecological environment with safety risks.

The main factors of potential ecological insecurity in Inner Mongolia mainly include the contribution rate of tertiary industry to GDP is too low. The proportion of coal in industrial value added is too large, the energy consumption of GDP and the pollution of million GDP. The amount of industrial wastewater and solid waste is much lower than the ideal level of ecological safety. Environmental protection and education and health investment is still very inadequate. These unsafe factors seriously threaten the ecological security situation in the region, it is necessary to carry out industrial restructuring, change the extensive mode of economic development, and take the road of sustainable ecological development.

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References

[1] Guan Wang. Study on the mechanism and evaluation of ecological safety evolution in coal resource-based cities [D]. Henan University of Technology, 2016.

[2] Puyang Xuehua, et al. Study on ecological environment Health assessment of golf course [J]. Journal of Grass Industry, 22(4):266-274.

[3] Deng Nan, Construction and empirical study of ecological security early Warning system in resource-based cities [D]. Xi’an polytechnic university, 2018.

[4] Yang Jinbin. Study on Environmental impact Assessment Index System of Dianchi wetland [J]. Environmental Science Guide, 2012, 3:42-47.

[5] Yuan Yuan, Bailin, Zhu Yanbao. Study on the measurement of low carbon ecological development level in coal resource cities based on PSR model [J]. Journal of Huainan Normal University, 2017 (6): 22-27.

[6] Zhong Yongde, et al: Hangzhou low carbon eco-city evaluation system design and empirical research. Sino-South University of Forestry Science and Technology journal, 2014 issue 6th.

[7] Zhao, Guojie, Hao Wensheng. Low-Carbon Eco-City: Research on Three-dimensional Objective Comprehensive Evaluation Method. Urban Studies 6 (2011): 7.

[8] Yang Wenpei, Wang Jianmin. Low carbon Traffic Theory. Beijing: China Environment Press, 2015.