Constructing the Evaluation System of Urban Land Ecosystem Based on Entropy Method and Analytic Hierarchy Process——Taking Shaanxi Province as an Example

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Abstract. The article establishes the ecosystem evaluation system of saline-alkali land in Shaanxi Province by using soil index, environmental index, biological index, productivity index and sustainable development index, and uses entropy method and analytic hierarchy process to determine the weight of index evaluation system. Finally, the practice and evaluation of the saline-alkali land ecological management method in Shaanxi Province was carried out, and it was found that the establishment of the index system has theoretical and practical significance.

1. Introduction

Urban ecological security refers to the support conditions of an urban ecological environment and the ecological and environmental problems which do not threaten its survival and development, that is, the function of urban ecosystem can meet the needs of its sustainable survival and development [1]. Ecological safety evaluation has become a research hotspot in related fields [2]. However, due to the lack of understanding of the connotation of ecological security, there has not been a consensus on the evaluation index system and research methods [3]. Commonly used ecological safety assessment methods include: exposure-response analysis model, comprehensive index method, fuzzy comprehensive evaluation method, ecological carrying capacity analysis method and landscape ecology method. In recent years, the ecological security system evaluation method based on entropy method and analytic hierarchy process has been widely applied to typical geographical regions or ecosystems at regional scales [4].

The distribution of saline-alkali land in Shaanxi Province is relatively wide, and the improvement of saline-alkali land is an important way to ensure the safety of grain production in Shaanxi Province. The comprehensive management of saline-alkali land in Shaanxi Province is aimed at harmonious ecology, and it needs a set of scientific comprehensive, standard and practical indicator systems and methods to measure and evaluate. At present, there are many questions about the standards and applications of the ecosystem evaluation system in China. There are deviations in the actual ecosystem management activities. For the evaluation of ecosystems, the focus is on rivers, lakes, grasslands, wetlands, highways and cities. The lack of saline-alkali land management research methods and system management control measures, and the current major ecosystem evaluation methods are not perfect, and the versatility is poor, and further research is needed [5]. Based on the management of saline-alkali land as a harmonious ecosystem and high-yield and stable-yielding farmland system, this paper studies the evaluation system of saline-alkali soil system after reaching the harmonious...
ecosystem from various angles, and verifies the rationality of the establishment of this index system in combination with the practice of saline-alkali land management and evaluation.

2. Establishment of land ecosystem evaluation index system for saline-alkali land in Shaanxi Province

In the selection and determination of the indicator system, the author has established some representative land ecosystem evaluation indicators by establishing five indicators: soil indicators, environmental indicators, biological indicators, productivity indicators and sustainable development indicators, which can meet the actual situation of the land. The specific indicator system is shown in the table as below.

Table 1. Evaluation system for land ecosystem index of saline-alkali land in Shaanxi Province

| Target layer | Criteria layer | Indicator layer | Indicator description |
|--------------|----------------|-----------------|----------------------|
| (A)          | Soil index (B1)| Soil organic matter content (C1) | Soil fertility |
|              |                | Soil pH (C2)    | Use pH to determine |
|              |                | Soil salinization degree (C3) | The process of salt accumulation and slow deterioration |
|              | Habitat indicator (B2) | Air quality (C4) | Comprehensive pollution index method |
|              |                | Water quality (C5) | Comprehensive pollution index method |
|              |                | Irrigation guarantee rate (C6) | Evaluation of farmland irrigation capacity |
|              | Biological indicators (B3) | Crop diversity (C7) | Realize land resource optimization |
|              |                | Aquatic biodiversity (C8) | Evaluation of water quality |
|              | Farmland wildlife diversity (C9) | The role is to improve soil quality |
|              | Productivity Indicators (B4) | Land productivity (C10) | Product output (output value) / land area |
|              |                | Energy production rate (C11) | Total output energy / total energy input |
|              | Sustainable Development Indicators (B5) | Ecological adaptability (C13) | Ecological adaptability of crops and environment |
|              |                | Resilience (C14) | Annual disaster rate |
|              |                | Productivity stability (C15) | Yield change rate |

3. Application of Analytic Hierarchy Process and Entropy Method in Evaluation Index System

Analytic Hierarchy Process (AHP) is a widely used and recognized method for the environmental assessment of ecosystem. This paper will also use AHP as the core computational method. However, the analytic hierarchy process is not perfect. The biggest shortcoming is that the weight of the index is lacking. It is often obtained through subjective methods such as expert scoring. Due to the subjectivity of the weight, the final result will be inaccurate. In order to make up for this deficiency, this paper first uses the analytic hierarchy process to determine the weight of each evaluation index, and then supplements the entropy method to improve the index weight.

3.1 Analytic hierarchy process to determine indicator weights

Assuming that the element B of the previous layer is used as a criterion, it has a dominant relationship with the elements C1, C2, ..., Cn of the next level. The establishment of the judgment matrix is to assign the corresponding weights of C1, C2, ..., Cn according to their relative importance under criterion C, that is, to repeatedly weigh the importance of criterion C, the two elements C1 and C2, and here we need to use the 9-point ratio [5]. The scale assigns importance to importance. If the factor i is compared with j by aij, the factor j is compared with i and judged as 1/aij. The consistency test is performed on the evaluation results using the formula (1), and the formula is as follows.

$$CI = \frac{\lambda_{max} - n}{n - 1}$$  (1)

Then determine the indicator weights, there are formulas as follows.

$$\bar{w}_i = n \prod_{j=1}^{n} a_{ij} \quad (i = 1, 2, 3, ..., n)$$  (2)
Then, the normalized judgment matrices are added by columns according to formula (3), and then the entire column vector is normalized to obtain the normalized relative importance of the elements relative to the upper layer criterion.

$$\mathbf{w}_i = \frac{\mathbf{w}_i}{\sum_{i=1}^{n} \mathbf{w}_i} \quad (i = 1, 2, 3..., n) \quad (3)$$

Calculated the weights of the dimensions of the criteria layer relative to the indicators of the ecosystem, and obtain Table 2.

Table 2. Evaluation matrix and weight of land ecosystem index of saline-alkali land in Shaanxi Province

| A | B1 | B2 | B3 | B4 | B5 | W |
|---|----|----|----|----|----|---|
| B1 | 1  | 1/2| 1/2| 4  | 2  | 0.20|
| B2 | 2  | 1  | 1  | 3  | 4  | 0.35|
| B3 | 2  | 1/3| 1/2| 1  | 2  | 0.16|
| B4 | 4  | 2  | 1/4| 1  | 1/3| 0.12|
| B5 | 1/2| 1/2| 2  | 3  | 1  | 0.17|

Consistency test results: lmax = 6.329; CI = 0.0658; RI = 1.24; CR = 0.0531 < 0.1.

By analogy, the secondary indicators can be used to derive the weight of each level of indicators relative to the upper level indicators. The weights of various indicators of the saline-alkali land ecosystem in Shaanxi Province are as follows.

Table 3. Analytic hierarchy process to determine the weight of each indicator

| Target layer | Criteria layer | Weights | Indicator layer | Weights |
|--------------|---------------|---------|-----------------|---------|
| Saline-alkali land ecosystem index evaluation system (A) | Soil index (B1) | 0.20 | Soil organic matter content (C1) | 0.450 |
| | | | Soil pH (C2) | 0.275 |
| | | | Soil salinization degree (C3) | 0.275 |
| | | | Air quality (C4) | 0.330 |
| | | | Water quality (C5) | 0.452 |
| | | | Irrigation guarantee rate (C6) | 0.218 |
| | | | Crop diversity (C7) | 0.370 |
| | | | Aquatic biodiversity (C8) | 0.357 |
| | | | Farmland wildlife diversity (C9) | 0.273 |
| | Habitat indicator (B2) | 0.35 | Land productivity (C10) | 0.440 |
| | | | Energy production rate (C11) | 0.358 |
| | | | Labor productivity (C12) | 0.202 |
| | Biological indicators (B3) | 0.16 | Ecological adaptability (C13) | 0.355 |
| | | | Resilience (C14) | 0.259 |
| | Productivity Indicators (B4) | 0.12 | Productivity stability (C15) | 0.386 |
| | Sustainable Development Indicators (B5) | 0.17 | | |

3.2 Entropy method to determine the index weight

3.2.1 Raw data standardization processing. Converted as follows:

$$x_{ij} = \frac{\max \{a_{ij}\} - a_{ij}}{\max \{a_{ij}\} - \min \{a_{ij}\}} \quad (i = 1, 2, 3..., n) \quad (4)$$

In the formula, $\max \{a_{ij}\}$ and $\min \{a_{ij}\}$ respectively represent the maximum value and the minimum value among all the evaluation objects under the same indicator.

3.2.2 Calculate the characteristic weight of the i-th evaluated object under the j-th index:
\( P_y = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \quad (i=1,2,3...,n) \) \hfill (5)

3.2.3 Calculate the entropy value \( A \) of the j-th index, with the expression:

\[
e_j = -(\ln n)^{-1} \sum_{i=1}^{m} p_{ij} \ln p_{ij}
\]

If, \( p_{ij}=0 \) define \( \lim_{p \to 0} p_{ij} \ln p_{ij} = 0 \). If \( x_{ij} \) is equal for a given j, then \( p_{ij}=1/n \), then \( e_j=1 \). Where \( n \) is the number of objects to be evaluated and \( m \) is the number of indicators.

3.2.4 Calculate the difference coefficient of index \( x_j \). The greater the difference coefficient \( q_j = 1 - e_j \), \( q_j \) more attention should be paid to the role of this indicator.

3.2.5 Determine the weight. Using the entropy value to calculate the objective weighting expression of each indicator is:

\[
w_j = q_j / \sum_{j=0}^{m} q_j \quad (j=0,1,2...,m)
\] \hfill (7)

According to the above steps, the weights of each indicator under various dimensions of the saline-alkali land ecosystem in Shaanxi Province are obtained, as shown in Table 4.

Table 4. Fuzzy comprehensive index weights determined by entropy determination method

| Soil index (B1) | 0.325 | Habitat indicator (B2) | 0.112 | Biological indicator (B3) | 0.225 | Productivity Indicator (B4) | 0.158 | Sustainable Development Indicators (B5) | 0.180 |
|----------------|-------|------------------------|-------|---------------------------|-------|-----------------------------|-------|----------------------------------------|-------|
| B11            | 0.310 | B12                    | 0.425 | B13                       | 0.265 | B21                         | 0.352 | B22                      | 0.245 | B23                         | 0.403 | B31                         | 0.514 | B32                      | 0.253 | B33                         | 0.233 |
|                |       |                        |       |                           |       | B41                         | 0.512 | B42                      | 0.210 | B43                         | 0.278 | B51                         | 0.335 | B52                      | 0.289 | B53                         | 0.376 |

3.3 Comprehensive weight determination

The weights obtained by the analytic hierarchy process belong to subjective weights, and the weights obtained by the entropy method belong to objective weights. In order to make the weight of each indicator more scientific and reasonable, this paper will combine the above two methods to determine the weight of indicators in each dimension and each dimension layer.

4. Specific application of the evaluation index system

The ancient beach of Halbo Beach was called "Luyang Lake". Due to the tectonic structure, the lake water gradually infiltrated into the beach at the end of the Ming Dynasty, forming a trough-shaped closed depression with high middle and low circumference. Due to the topographical characteristics of the brine beach and the use of the diversion irrigation and flood diversion and siltation project in the Luoxi Irrigation District, the drainage channel in the beach area is silted, the groundwater level in the beach area is rising, the salinization of the land is gradually serious, and the land in the beach area is long and ridiculous. Land resources are idle [6]. The area undeveloped soil test data showed that the average content of soil organic matter was 0.70%, the average salt content was 0.774%, and the average pH value was 9.33, which was not conducive to crop growth. In 1999, the project began to develop 254.8hm² of saline-alkali wasteland and 26.4hm² of new cultivated land. The main projects
include excavation of drainage tanks, reservoirs, land leveling, roads and field structures, and irrigation systems.

Table 5. Evaluation results of secondary indicators of salinized saline land

| Secondary indicators                  | Comprehensive weight | Level evaluation   |
|--------------------------------------|----------------------|--------------------|
| Soil organic matter content (C1)     | 0.38                 | Middle soil        |
| Soil pH (C2)                         | 0.35                 | Middle soil        |
| Soil salinization degree (C3)        | 0.27                 | Middle soil        |
| Air quality (C4)                     | 0.341                | suitable           |
| Water quality (C5)                   | 0.349                | suitable           |
| Irrigation guarantee rate (C6)       | 0.311                | Very suitable      |
| Crop diversity (C7)                  | 0.442                | Diversified high   |
| Aquatic biodiversity (C8)            | 0.305                | General diversity  |
| Farmland wildlife diversity (C9)     | 0.253                | General diversity  |
| Land productivity (C10)              | 0.476                | High productivity  |
| Energy production rate (C11)         | 0.284                | Productivity in general |
| Labor productivity (C12)             | 0.24                 | Productivity in general |
| Ecological adaptability (C13)        | 0.345                | Sustainable        |
| Resilience (C14)                     | 0.274                | Sustainability     |
| Productivity stability (C15)         | 0.381                | Sustainable        |

The crop varieties in the regional crops are diverse, the wild animals in the field increase, the water in the ditch is preserved, and the fish breed and float. Animal survival, the regional environment has been significantly improved, and a harmonious ecology has been gradually constructed and formed. Therefore, this paper applies the evaluation method of saline-alkali land harmonious ecosystem, and analyzes the feasibility and rationality of the treatment measures. The specific results are as follows: The comprehensive evaluation result of salinity and alkali-alkali land is $S=86.709$, and the evaluation results show that the ecological restoration of brine-alkali land the system is healthy. After implementing different projects to improve soil, it is suitable for crop growth, regional air water quality is high, ecosystem is sustainable, and overall is good, indicating the feasibility and rationality of the implementation of the project, and the evaluation method has good applicability.

5. Conclusion

As a systematic project, comprehensive evaluation of ecosystems requires a trade-off between different ecosystem products and service functions, a health diagnosis and evaluation of ecosystems, and a scientific basis for ecosystem management. They have a close relationship and are a relatively complete system. The purpose of ecological evaluation is management, and the basis of management is the status assessment of the ecosystem and the prediction of future trends. The task of management is to adjust the status of ecosystem functions. For the current research, the following difficulties need to be overcome: Firstly, we must weigh the relationship between different ecosystem products and service functions. This requires long-term effects and short-term benefits to be considered simultaneously and achieve sustainable development. Secondly, ecosystem services, health diagnosis and management and their evaluation should be expanded on a time and space scale. For complex ecosystems, only by changing the law of change in time, spatially studying the interaction between and within ecosystems, comprehensive evaluation can get correct results. Thirdly, ecosystem service function and health diagnosis the establishment of the indicator system. Different indicator systems on different spatial scales, how to properly establish and use these indicators requires researchers to consider different situations. Fourthly, The organic combination of ecosystem products, services, health and management is necessary.
References

[1] Xu Huan, Li Meimei, Liang Haibin, et al. Advances in the evaluation index system of degraded forest ecosystems. Acta Ecological Sonica, Vol. 24 (2011) No.38, p. 58-61.

[2] Guo Linna, Zhang Menghua, Wang Hainan. Evaluation of Agricultural Ecosystem in Tangshan City Based on Energy Theory. Research of Soil and Water Conservation, Vol. 2(2017) No.11. p. 35-41.

[3] Zhang Lieyu. The Health Assessment of Lake Water Ecosystem Based on Subjective and Objective Weighted Fuzzy Comprehensive Evaluation Method. Journal of Lake Science. Vol. 5 (2017) No.14, p. 18-22

[4] Health Assessment of Typical Mangrove Wetland Ecosystem in Guangxi Based on Landscape Features. Journal of Safety and Environment,2017(3). Vol. 3 (2017) No.21, p. 15-19.

[5] XU Xianghong, WANG Ting-ting, LEI Wen-wen, et al. Evaluation and Analysis of Coupling Technology of Oasis Integrated Ecosystem Management in Jingdian Irrigation District. Grass science, Vol. 6 (2010) No.27, p. 38-44.