Evaluation of Ecological Benefits of Corn Straw Back in Liaozhong North Based on Fuzzy Evaluation

Gao Xiang¹, Zhao Dan¹ and Yang Ping¹,², *  
¹ College of Information and Electrical Engineering, Shenyang Agricultural University, Shenyang, 110866, China  
² Liaoning Agricultural Information Technology Center, Shenyang 110866,China  
* Corresponding author’s e-mail: xdxy7128@126.com

Abstract: Taking Cainiu Town, Tieling City, Liaoning Province as the main research area, the four evaluation index factors of water, fertilizer, gas and soil were selected through investigation and data collection. The method of combining fuzzy evaluation method and analytic hierarchy process is used to analyze the ecological aspects of comprehensive ecological links such as straw returning to grass, clear ridge returning to field, strip returning to field, deep rotation returning to field and strip returning to field. The final EBI index is obtained by multiplying the matrix by fuzzy analysis method, and then the EBI index and the grade corresponding to the score of the review are compared to get the final judgment result, and the comprehensive ecological benefit index is the final result. Obviously from the results, the comprehensive ecological benefits of soil and water conservation, carbon and oxygen fixation, and water bodies have improved significantly.

1. Introduction
The central and northern parts of Liaoyang, Shenyang and Tieling in Liaoning Province have flat terrain, moderate rainfall and sufficient light and heat resources. The annual average temperature is 7°C~8°C, the frost-free period is about 150 days, the annual rainfall is about 650mm, and the annual sunshine hours are 2570~2930 hours. The corn planting area is about 12.04 million mu, and the average yield is 456 kg/mu [1]. The annual crop straw production is about 34 million tons, and the comprehensive utilization of straw is 23.12 million tons, the remaining straw is used directly for rural living fuel, or directly open-air combustion, resulting in great carbon dioxide and other gas pollution, become one of the culprits of polluted air. At present, the Liaoning Provincial Government has formulated and promulgated the "Liaoning Provincial People's Government Office on promoting the comprehensive utilization of crop straw and the implementation of the work (2016-2018)”, clearly defined the comprehensive utilization of crop straw and the overall requirements of the work of the prohibition of burning. Therefore, the effective use of straw resources and research on straw returning technology is an effective measure to improve the ecological environment of crops and improve soil structure and water resources.

Based on fuzzy comprehensive evaluation and analytic hierarchy process, the effects of rotary tillage optimization and straw overturning technology on ecological benefits were evaluated, and a multi-factor evaluation index system was established. By studying carbon dioxide, organic matter,
fertilizer, water content and other aspects, the results are quantitatively determined by specific numerical values, which solves the problem that it is difficult to quantitatively solve the ecological benefits, and has certain practical significance and innovation.

2. Methods Introducing

2.1. Analytic hierarchy process AHP

• Construct a hierarchical model of the indicator hierarchy.
  • Construct a judgment matrix after comparing indicators \( a=(A_i)_{n,n} \)
  • Hierarchical single sorting and hierarchical total sorting
  • Hierarchical sequencing is the importance of determining factors, and is used to calculate the Hierarchical ordering is the importance of determining factors. It is used to calculate the eigenvector \( \lambda_{\max} \) of the judgment matrix \( A \), including hierarchical single ordering and hierarchical total sorting. To perform single ordering on the secondary indicators. Firstly, the judgment matrix \( A \) of the secondary indicators for the primary indicators is constructed, and then the feature vector \( W \) and the maximum eigenvalue \( \lambda_{\max} \) of the judgment matrix \( A \) are calculated.

The feature vector and the maximum eigenvalue are calculated. First, the matrix \( A \) is normalized by column to obtain the matrix \( M \). Its calculation formula is:

\[
M = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}
\]  

(1)

Add the elements of matrix \( M \) by row to get the vector \( a=(a_1, a_2, a_j, \ldots, a_n) \). Then normalize it to get the eigenvector \( W=(W_1, W_2, W_j, \ldots, W_n) \). Its calculation formula is:

\[
W_i = \frac{a_i}{\sum_{i=1}^{n} a_i}
\]

(2)

The feature vector is the hierarchical weight value of each indicator, and the result is also the hierarchical single order. After the calculation, the maximum eigenvalue is calculated. Its calculation formula is:

\[
\lambda_{\max} = \frac{1}{n} \sum_{i=1}^{n} (A\omega)_{i}
\]

(3)

• Consistency test.
• Determination of the weight coefficient[2].

2.2. Fuzzy analysis

The basic steps of the fuzzy evaluation method are:

• First determine the factor domain of the evaluation object
  N evaluation indicators can be set. Among them[3]: N indicates the number of evaluation indicators, which is determined by the specific indicator system.
• Determine the rating hierarchy
  Assume \( A = (A_1, A_2, \ldots, A_n) \), each level corresponds to a fuzzy subset, a level set. \( A_i \) represents the \( n \)th evaluation result, \( A \) represents the review level set.
• Establish fuzzy relation matrix
  After constructing the hierarchical fuzzy subset[4], it is necessary to quantify the evaluated objects from each factor \( (i=1, 2\ldots m, j=1, 2\ldots n) \) one by one, then get a fuzzy relation matrix \( R_{ij} \).
\[
R = \begin{bmatrix}
r_{11} & r_{12} & \cdots & r_{1n} \\
r_{21} & r_{22} & \cdots & r_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
r_{m1} & r_{m2} & \cdots & r_{mn}
\end{bmatrix}
\]

(4)

\(R\) represents the degree of membership of a vague subset of hierarchy from \(N\) to \(An\).

- Determine the weight vector of the evaluation factor

In the fuzzy comprehensive evaluation, determine the weight vector of the evaluation factor \(U = (u_1, u_2, \ldots, u_n)\), \(U\) represents the power vector of evaluation factors. The analytic hierarchy process is generally used to determine the order of relative importance between evaluation indicators to determine the weight coefficients and normalize them prior to synthesis.

- Synthesize Fuzzy Comprehensive Evaluation Results Vector.

The \(U\) is combined with the \(R\) of each evaluated object[5] to obtain a fuzzy comprehensive evaluation result vector \(B\) of each evaluated object[6].

\[
B = U \times R = [u_1, u_2, \ldots, u_n]
\]

(5)

- Analyze fuzzy comprehensive evaluation result vector[7,8].

Calculate the final comprehensive evaluation score based on the fuzzy comprehensive evaluation results

3. Construction of Fuzzy Comprehensive Evaluation Index System of AHP

3.1. Ecological benefit weight calculation

- Set up four indicator factors for evaluating ecological benefits \(U = (u_1, u_2, u_3, u_4)\)

\(u_1\)——The co benifit \(u_2\)——The fertilizer efficiency \(u_3\)——The solid soil benefit \(u_4\)——The water storage benefit

- Comparison matrix \(A\)

The four indicators are compared with the importance of ecological benefit to get matrix \(A\). Find the eigenvector corresponding to the eigenvalue of \(A\) and normalize it to obtain the weight coefficient of the index under the evaluation target. (The comparison is in accordance with table 1[9] below.)

| Importance Standard Value | meaning |
|---------------------------|---------|
| \(aij = 1\)              | Element i is the same as element j for the above level of factors; |
| \(aij = 3\)              | Element i is slightly more important than element j; |
| \(aij = 5\)              | Element i is more important than element j; |

Table 1. Evaluation factor importance standard value meaning table
aij = 7 Element i is much more important than element j;
aij = 9 Element i is extremely important than element j;
aij = 2, 4, 6 The importance of the elements i and j is intermediate between the above judgments.

reciprocal The ratio of the importance of element i to element j is aij, and the ratio of element j to element i is 1/aij.

After two comparisons of the four indicators, the judging matrix is obtained as shown below:

\[
A = \begin{bmatrix}
1 & 9 & 3 & 7 \\
1/9 & 1 & 1/7 & 3 \\
1/3 & 7 & 1 & 7 \\
1/7 & 1/3 & 1/7 & 1 \\
\end{bmatrix}
\] (6)

In the formula:
- \(A_1\) — Weight value of carbon dioxide benefit
- \(A_2\) — Weight value of fattening benefit
- \(A_3\) — Weight value of soil consolidation benefit
- \(A_4\) — Weight value of water storage benefit

\[ \text{• Use } Z_j = \frac{Z_{ij}}{\sum Z_{ij}} \text{ to find feature vectors and establish a new matrix } Z ]

\[
Z = \begin{bmatrix}
0.630 & 0.519 & 0.700 & 0.389 & 2.238 \\
0.070 & 0.058 & 0.033 & 0.167 & 0.328 \\
0.210 & 0.404 & 0.233 & 0.389 & 1.236 \\
0.090 & 0.019 & 0.033 & 0.056 & 0.198 \\
1 & 1 & 0.099 & 1.001 & 4 \\
\end{bmatrix}
\] (7)

Available feature vectors:

\[
Z_j = \begin{bmatrix}
2.238 \\
0.328 \\
1.236 \\
1.198 \\
\end{bmatrix}
\] (8)

\[ \text{• Use } W_j = \frac{Z_j}{\sum Z_j} \text{ the normalization process to derive the weights of the four indicators.} \]

| Table 2 Evaluation factor weight table |
|-----------------------------------------|
| Z | Z1 | Z2 | Z3 | Z4 | SUM2 | W | W% |
|---|----|----|----|----|------|---|----|
| Z1 | 0.630 | 0.519 | 0.700 | 0.389 | 2.238 | 0.5595 | 55.95% |
| Z2 | 0.070 | 0.058 | 0.033 | 0.167 | 0.328 | 0.0820 | 8.20% |
| Z3 | 0.210 | 0.404 | 0.233 | 0.389 | 1.236 | 0.3090 | 30.90% |
| Z4 | 0.090 | 0.019 | 0.033 | 0.056 | 0.198 | 0.0495 | 4.95% |
| SUM1 | 1 | 1 | 0.999 | 1.001 | 4 | 1 | 1 |

Table: \(SUM_1\) — Sum of columns of a matrix
\(SUM_2\) — Sum of matrix rows
W — Evaluation factor weight value column
W% — The percentage of W
Figure 1. Evaluation factor weight map

As shown in the figure 1, the CO2 benefit accounted for 60.9%, the fertilizer efficiency accounted for 8.9%, the solid soil benefit accounted for 24.6%, and the water storage benefit accounted for 5.4%.

$$A = \begin{bmatrix} 0.5595 & 0.0820 & 0.3090 & 0.0495 \end{bmatrix}$$ (9)

3.2. The establishment of comment sets and comment points

According to the actual situation of ecological benefit evaluation index system, the evaluation grade is divided into four grades: 

Comment set = [Very good  Alittle good  Little good  More harm than good ]

Using the formula and mastering the data, you can get the comment score corresponding to the comment set:

$$G = [14.75 11.25 7.25 3.25]$$ (10)

Carbon dioxide emissions during mechanization:

$$Q_{CO_2} = \frac{M \times P \times T \times X}{10000000}$$ (11)

- $Q_{CO_2}$ —— Carbon dioxide emissions from mechanization, g
- $M$ —— The mechanical power of the machines used
- $P$ —— Mechanical power used in the application of technology, kw
- $T$ —— Average annual mechanical working hours
- $X$ —— Fixed emission factor of carbon dioxide

Soil water content:

$$SWC = \frac{(m_1 - m_2)}{m_2} \times 100\%$$ (12)

- $SWC$ —— Soil moisture content, \%
- $V_0$ —— The original soil weight, g
- $m_2$ —— Dried soil weight, g

Soil organic matter content :

$$OM = \frac{(V_o - V) \times C \times 0.003 \times 1.724 \times 1.10 \times 1000}{m}$$ (13)

- $OM$ —— Soil organic matter mass fraction, the unit is g/kg;
- $V_o$ —— The volume of ferrous sulfate standard solution consumed in the blank test, the unit is mL;
- $V$ —— The sample is used to determine the volume of the ferrous sulfate standard solution consumed, the unit is mL;
Concentration of ferrous sulfate standard solution, the units is mol/L; 0.003 — Millimol of 1/4 carbon atom, in units of millimoles g; 1.724 — The coefficient of converting organic carbon into organic matter; 1.10 — Oxidation correction factor m — The quality of the extracted arch dry specimen, the units is g; 1000 — Converted to a mass score per kilogram.

3.3. Composite membership matrix R
The membership degree is determined by comparing the corresponding single factor comment score with the corresponding difference and the composite matrix R is as follows:

\[
R = \begin{bmatrix}
0 & 0.15 & 0.3 & 0.55 \\
0.5 & 0.375 & 0.125 & 0 \\
0.5 & 0.33 & 0.17 & 0 \\
0.5 & 0.3 & 0.2 & 0
\end{bmatrix}
\]  

(14)

3.4. Comprehensive fuzzy evaluation calculation
• Calculate the evaluation result matrix

\[ B = A \times R = \begin{bmatrix} 0.1322 & 0.3450 & 0.3593 & 0.3622 \end{bmatrix} \]

(15)

" • " represents the fuzzy arithmetic, which takes matrix multiplication in this model. B represents the evaluation result matrix, represents the degree of membership of the rated object's health status on the comment set V.

• Define a physical quantity EBI

\[ EBI = B \times G = 9.626275 \]

(16)

EBI (Ecological Benefit Index) represents the ecological benefit index, between 11.25 and 7.25.

3.5. Explanation of the results of the evaluation
The evaluation result matrix B can be explained in two aspects: (1) \( b_i \) indicates the degree of membership of the ecological benefit pair \( v_j \). According to the principle of maximum membership[10], the evaluation \( v_i \) corresponding to the maximum membership degree \( b_i \) represents the evaluation of the ecological benefit status; (2) The results of the eco-efficiency evaluation corresponding to the scores of the scores reflected by the score indicators.

This paper adopts Method 2 to define the physical quantity EBI to represent the ecological benefits. The final EBI score is 8.4111, between 11.25 and 7.25. Then the ecological benefit situation should belong between \( V_2 \) and \( V_3 \). The results show that the ecological benefits of the test area for the implementation of the strip deep-stalk straw returning technology are beneficial to the environment.

3.6. The overall calculation formula and simulation of ecological benefit evaluation system
3.6.1. The eco-benefit evaluation model is constructed from the weight value as follows:

\[ M = \alpha N_1 + \beta N_2 + \gamma N_3 + \delta N_4 \]

(17)

M —— Ecological benefits \( N_1 —— \) Carbon dioxide emission \( \beta, \gamma, \delta —— \) Weights for each of the four indicators

3.6.2. Simulation testing
As shown in Figure 2 and Figure 3, the two methods of applied technology and unapplied technology are compared. It can be intuitively seen that the ecological benefit of applied technology is significantly higher than that of unapplied technology through different values of indicator factors.

As shown in Figure 4, when the top of the image is the straw returning technology, the image below is the ecological benefit evaluation model of the straw-free field. The figure adopts a three-dimensional form, and the Z-axis represents ecological benefits. It can be clearly seen from the figure that there is a difference in the ecological benefits between technology and technology, and thus visually demonstrates the beneficial effects of ecological benefits in technology.

4. Conclusion and analysis
The ecological benefit evaluation of the central and northern regions of Liaoning was carried out, and the changes in ecological benefits after the implementation of the straw returning technology in the region were analyzed. The evaluation system is constructed from four aspects: carbon dioxide efficiency, soil solidification benefit, fertilizer conservation benefit, and implicit water source benefit. The index factors are carbon dioxide, water, fertilizer and organic matter. The calculation results show that the ecological benefits are also improved at the same time, after the clearing and mulching of the straw, the deep rotation of the strips, and the strips are re-used, the results of the research prove that the area where the straw returning technology is applied and the straw is not carried out. Compared with the area of returning to the field, the ecological benefits have improved.

References.
[1] Yu Pengxiang, Zhang Wenke, Menan, Tian Ping, Wang Yingxuan, Sun Yue, Meng Guangxin, Su Yehan, Qi Hua. The influence of different straw return methods on spring corn yield, water utilization and root growth [J]. Journal of soil and water conservation, 2018, 32(04): 255-261.
[2] Dai Mengna, Wu Zhongli, Liu Yongwen, Yin Ping, Zhang Jianhua, Teng Wenjie. Weight Study of clinical teacher's classroom teaching quality evaluation index system - Based on hierarchical analysis [J]. Research and practice in medical education, 2019, 27(03):396-399+425

[3] Sun Xiangyu. Internet of things security and risk assessment [D]. Hebei normal university, 2013

[4] Xibo Sun. Study on the Evaluation of Social Stability Risk of Agricultural Transferring Populations Citizenization Based on Fuzzy Analytic Hierarchy Process [A]. Wuhan Zhicheng Times Cultural Development Co., Ltd. Proceedings of 2nd International Conference on Economics and Management, Education, Humanities and Social Sciences (EMEHSS 2018) [C]. Wuhan Zhicheng Times Cultural Development Co., Ltd: Wuhan Zhicheng Times Cultural Development Co., Ltd., 2018: 12

[5] DU Lunfang. Ideological Change Research on Political Ideology Education of the Party Members Based on Fuzzy Analytic Hierarchy Process [A]. International Informatization and Engineering Associations, Atlantis Press. Proceedings of 2015 International Conference on Education Technology, Management and Humanities Science (ETMHS2015) [C]. International Informatization and Engineering Associations, Atlantis Press: Computer Science and Electronic Technology International Society, 2015: 4

[6] Jinpeng Qiu. Investment Risk Assessment of Co-generation Based on AHP-FCM [A]. International Informatization and Engineering Associations, Atlantis Press. Proceedings of 2015 3rd International Conference on Education, Management, Arts, Economics and Social Science (ICEMAESS 2015) [C]. International Informatization and Engineering Associations, Atlantis Press: Computer Science and Electronic Technology International Society, 2015: 4

[7] Dong Jiefang, Gao Xuemei. Tourist Satisfaction Evaluation based on Fuzzy Comprehensive Evaluation Method [J]. Journal of yuncheng university, 2019, 37(03): 20-24.

[8] Yu Pengxiang, Zhang Wenke, Menan, Tian Ping, Wang Yingxuan, Sun Yue, Meng Guangxin, Su Yehan, Qi Hua. The influence of different straw return methods on spring corn yield, water utilization and root growth [J]. Journal of soil and water conservation, 2018, 32(04): 255-261

[9] Ke Liu. The Analysis of Schedule Control of Construction Project Using AHP Methods [A]. Research Institute of Management Science and Industrial Engineering. Proceedings of 2017 3rd International Conference on Economics, Social Science, Arts, Education and Management Engineering (ESSAEME 2017) [C]. Research Institute of Management Science and Industrial Engineering: Computer Science and Electronic Technology International Society, 2017: 4

[10] Wei-liang ZHU. Research of Intelligence Simulation Experiment System Based on Fuzzy AHP and FFT Algorithm [A]. Advanced Science and Industry Research Center. Proceedings of 2014 International Conference on Artificial Intelligence and Software Engineering (AISE 2014) [C]. Advanced Science and Industry Research Center: Science and Engineering Research Center, 2014: 5