ENGINEERING Agriculture, https://journal.hep.com.cn/fase
Jiangtao WANG et al., *ENGINEERING Agriculture*, 2027, 14(3): 27738
https://doi.org/10.15302/J-FASE-2027738
RESEARCH ARTICLE

An innovative vegetable-flower-oil canola (*Brassica napus*) cropping system increases crop yields and economic returns, while reducing environmental impact in the Erhai Lake Basin

Jiangtao WANG[*1,2,3], Shuntao ZHANG[*1,3,4], Jing YANG[3,5], Kang WANG[1,3,6], Feiyu YING[1,3], Jianwei LU[7], Hans LAMBERS[1,8], Wen-Feng CONG(✉)[1,3,9]

1 State Key Laboratory of Nutrient Use and Management, Key Laboratory of Plant-Soil Interactions (Ministry of Education), College of Resources and Environmental Sciences, National Academy of Agriculture Green Development, China Agricultural University, Beijing 100193, China.
2 College of Agriculture, Henan University of Science and Technology, Luoyang 471000, China.
3 Erhai Academy of Agriculture Green Development, Dali 671008, China.
4 College of Resources and Environment, Henan Agricultral University, Zhengzhou 450046, China.
5 Yunnan University Resource Plant Research Institute, Kunming 650504, China.
6 School of Chemistry and Chemical Engineering, Dezhou University, Dezhou 253023, China.
7 College of Resources and Environment, Huazhong Agricultural University, Wuhan 430070, China.
8 School of Biological Sciences and Institute of Agriculture, University of Western Australia, 35 Stirling Highway, Perth, WA 6009, Australia.
9 College of Resources and Environmental Sciences, Yunnan Agricultural University, Kunming 650201, China.

*These authors contribute equally to the work.

Received February 24, 2026;
Accepted July 13, 2026.
Correspondence: wenfeng.cong@cau.edu.cn
© The Author(s) 2027. Published by Higher Education Press. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0)

SUPPLEMENTARY MATERIALS

Detailed Calculations for Entropy Weight Method and TOPSIS Relative Closeness (C_i)

This material supplements the calculation logic in Section 2.3.9, providing specific formulas, symbol definitions, and parameter settings for reproducibility—Including detailed steps for entropy weight derivation and TOPSIS relative closeness (C_i) calculation.

1 Detailed calculation for indicator weights via entropy weight method

Step 1: Standardization of original indicator data

Raw data of 13 indicators were standardized to eliminate interference from inconsistent dimensions and attribute orientations (positive/negative indicators):

For positive indicators (higher value indicates better performance, e.g., *IWUE*, economic benefits), the standardization formula is:

$$y_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \qquad (1)$$

For negative indicators (lower value indicates better performance, e.g., apparent nitrogen surplus, total production cost), the standardization formula is:

$$y_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \qquad (2)$$

Symbols:

x_{ij}: Original value of the j-th indicator for the i-th evaluation sample (i=1, 2, 3, 4, corresponding to 4 cropping systems; j=1, 2, …, 13, corresponding to 13 indicators in Table 2);

y_{ij}: Standardized value of x_{ij} (range: 0 to1);

max(x_j): Maximum value of the j-th indicator across all samples.

min(x_j): Minimum values of the j-th indicator across all samples.

Step 2: Calculation of indicator proportion (f_{ij})

The proportion of the standardized value of the j-th indicator in the i-th sample was calculated to reflect sample importance within the indicator:

$$f_{ij} = \frac{y_{ij+\varepsilon}}{\sum_{i=1}^{n}(y_{ij} + \varepsilon)} \qquad (3)$$

Symbols:

n = 4: Number of evaluation samples (cropping systems);

$\varepsilon = 10^{-6}$: Small constant added to avoid calculation errors. This ensures that $\ln f_{ij}$ is defined when $y_{ij} = 0$; mathematically, when $f_{ij} \to 0$, $f_{ij}\ln f_{ij} \to 0$).

Step 3: Calculation of indicator entropy (e_j)

Entropy quantifies the degree of information disorder of an indicator. Lower entropy indicates stronger

discrimination among samples:

$$e_j = -k \sum_{i=1}^{n} f_{ij} \ln f_{ij} \quad (4)$$

Symbols:

$k = 1/\ln n$: Normalization coefficient, which ensures that $0 \leqslant e_j \leqslant 1$);

$e_j = 1$: The indicator provides no effective information (all samples have identical values); $e_j \to 0$: The indicator has strong discrimination among samples.

Step 4: Calculation of indicator entropy weight (w_j)

Entropy weight reflects the *j*-th indicator's relative contribution to comprehensive evaluation:

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{m}(1 - e_j)} \quad (5)$$

Constraints:

$0 \leqslant w_j \leqslant 1$ and $\sum_{j=1}^{m} w_j = 1$, which meets basic requirements of comprehensive evaluation;

Symbol:

$m = 13$: Number of evaluation indicators (Table 2).

2 Detailed calculation for TOPSIS relative closeness (C_i)

The following steps supplement the TOPSIS model application in Section 2.3.9 (3), focusing on formulas for weighted standardization, reference solutions, and relative closeness (C_i).

Step 1: Weighted standardization of indicator data

Based on entropy weights (w_j, derived from Section 1 above), the standardized indicator values (y_{ij}) were weighted to form a weighted standardized matrix *Z*, where each element Z_{ij} reflects the weighted contribution of the *j*-th indicator to the *i*-th sample:

$$Z_{ij} = w_j \times y_{ij} \ (i = 1, 2, \ldots, n; j = 1,2, \ldots, m) \quad (6)$$

Symbols:

Z_{ij}: Weighted standardized value of the *j*-th indicator for the *i*-th sample;

w_j: Entropy weight of the *j*-th indicator (from Formula 5);

y_{ij}: Standardized value of the *j*-th indicator for the *i*-th sample (from Formulas 1 or 2);

$n = 4$, $m = 13$: Same as defined above.

Step 2: Definition of ideal solution (Z^+) and negative-ideal solution (Z^-)

The ideal solution (Z^+) represents the hypothetical best performance across all indicators, taking the maximum value of each weighted standardized indicator:

$$Z^+ = \{Z_1^+, Z_2^+, \ldots, Z_m^+\} = \left\{\max(Z_{1j}, Z_{2j}, \ldots, Z_{nj}) \mid j = 1,2, \ldots, m\right\} \quad (7)$$

The negative-ideal solution (Z^-) represents the hypothetical worst performance across all indicators, taking the minimum value of each weighted standardized indicator:

$$Z^- = \{Z_1^-, Z_2^-, \ldots, Z_m^-\} = \left\{\min(Z_{1j}, Z_{2j}, \ldots, Z_{nj}) \mid j = 1,2, \ldots, m\right\} \quad (8)$$

Symbol:

Z_j^+ (or Z_j^-): Ideal (or negative-ideal) value of the *j*-th weighted indicator.

Step 3: Calculation of euclidean distances.

Euclidean distances between each sample (management practice) and the two reference solutions were computed to measure performance proximity:

The distance from the *i*-th sample to the ideal solution (D_i^+) is calculated as:

$$D_i^+ = \sqrt{\sum_{j=1}^{m} \left(Z_{ij} - Z_j^+\right)^2} \ (i = 1,2,\dots,n) \quad (9)$$

The distance from the *i*-th sample to the negative-ideal solution (D_i^-) is calculated as:

$$D_i^- = \sqrt{\sum_{j=1}^{m} \left(Z_{ij} - Z_j^-\right)^2} \ (i = 1,2,\dots,n) \quad (10)$$

Step 4: Calculation of relative closeness (C_i)

The relative closeness coefficient C_i quantifies the proximity of the *i*-th sample to the ideal solution relative to the negative-ideal solution:

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \ (i = 1,2,\dots,n) \quad (11)$$

Interpretation:

C_i ranges from 0 to 1;

$C_i \rightarrow 1$: The sample is very close to the ideal solution, indicating excellent comprehensive performance;

$C_i \rightarrow 0$: The sample is very close to the negative-ideal solution, indicating poor comprehensive performance.