Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 221 (2023) 593–600

Procedia Computer Science

www.elsevier.com/locate/procedia

Tenth International Conference on Information Technology and Quantitative Management

# Assessment on High-quality Development of Guizhou's Agricultural Economy Based on Hesitant Fuzzy Linguistic Term Sets

Wang-jing Xu[a,b], Mu Zhang[a,*]

[a]*School of Big Data Application and Economics, Guizhou University of Finance and Economics, Guiyang(550025), Guizhou, China*
[b]*Guizhou Institution for Technology Innovation & Entrepreneurship Investment, Guizhou University of Finance and Economics, Guiyang(550025), Guizhou, China*

**Abstract:**

In order to scientifically evaluate the quality of agricultural economic development in Guizhou's prefecture-level cities, the article constructs an index system for evaluating the quality development level of agricultural economy from four aspects, including optimization of agricultural economy structure, mechanization level of agricultural economy, green development of agricultural economy, and openness and sharing of agricultural economy, with reference to the current situation of agricultural economy development in nine cities and municipalities of Guizhou Province; and selects the original data of indicators from 2017 to 2021, and uses the hesitant fuzzy linguistic PROMETHEE method to the empirical evaluation of the quality of agricultural economic development was conducted. The empirical results show that Zunyi, Bijie and Guiyang have a high level of agricultural economic development, ranking among the top three in the province, and have a greater advantage in development level compared with other cities and municipalities, while Qianxinan Autonomous Prefecture has the lowest level of agricultural economic development. The level of high-quality development of the agricultural economy in Guizhou province shows overall growth but uneven regional development. In response to these problems, this paper gives policy advice.

© 2023 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the Tenth International Conference on Information Technology and Quantitative Management

*Keywords:* Agricultural Economic; Hesitant Fuzzy Linguistic Term Sets; PROMETHEE Method; High-quality Development; Guizhou Province

## 1. Introduction

Agriculture is the foundation of the national economy and plays a "hard support" role in the stability and

* Corresponding author. Tel.: +86-0851-88510575.
*E-mail address:* zhangmu01@163.com

1877-0509 © 2023 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of the Tenth International Conference on Information Technology and Quantitative Management
10.1016/j.procs.2023.08.027

development of the national economy and society. The development of the agricultural economy is not only a prerequisite for and a guarantee of social and economic development, but also an important part of the material production of society, and has a decisive strategic position in the national economy. In 2017, the 19th Party Congress put forward the strategy for rural revitalization, which promoted the sustainable development of China's agricultural economy and also had far-reaching implications for the overall construction of a well-off society in China. In 2020, the Proposal of the Central Committee of the Communist Party of China on Formulating the Fourteenth Five-Year Plan for National Economic and Social Development and the Visionary Goals for 2035 clearly states that we should adhere to the priority development of agriculture and rural areas, grasp the meaning and significance of high-quality agricultural development in the new era, and continue to enhance the level of people's well-being.

The scientific evaluation of the high-quality development of the agricultural economy is a fundamental and key issue in promoting agricultural supply-side reform, consolidating the achievements of poverty eradication and promoting the strategy of rural revitalization in a comprehensive manner. At present, research on high-quality agricultural development mainly focuses on constructing corresponding development indicator systems from specific agricultural industries, which are used to measure and study their development levels and influencing factors. In terms of indicator systems, Wang et al. (2023) [1] constructed an evaluation indicator system for high-quality development of agricultural economy from five aspects: innovation-driven, intensive and efficient, coordinated and inclusive, green and ecological, and open and shared. Huang et al. (2020) [2] constructed a system of indicators for high-quality agricultural development that includes product quality, industrial efficiency, production efficiency, operator quality, international competitiveness, farmers' income, and green development. Zhang et al. (2023) [3] examine the coordination dimension of the agricultural economy mainly in terms of the income level of rural people, arguing that the indicators of the rural people's income level indicator layer reflect the structure of the rural economy to a certain extent.Zhang et al. (2022) [4] use the new development concept of "innovation, coordination, green, openness and sharing" as a guide to build an indicator system for high-quality development of the agricultural economy.They argue that quality agricultural development emphasises a people-centred approach and therefore choose the indicator "per capita disposable income of rural people" to measure the distribution of results in the dimension of "sharing the welfare of the agricultural economy".The system is based on the following five dimensions Liang and Zhao (2021) [5] divided the comprehensive evaluation system of agricultural economy in southwest China into three categories: economic, ecological and social. Zhang and Yang (2021) [6] constructed a primary evaluation index system of agricultural economic development level from three aspects: green economy, green agriculture and population development.

The hesitant fuzzy linguistic term set was proposed by Rodríguez et al (2012) [7] and has now been widely used in various aspects of urban business environment evaluation [8], security risk assessment [9], and scenario decision making [10]. The PROMEHTEE method, proposed by Brans et al (1985) [11], is a multi-attribute decision making method based on a two-by-two comparison of the relationship between the preferences of options. If the decision maker adopts the hesitant fuzzy language PROMEHTEE method for decision analysis, then the preference function and the weights of each attribute given by the decision maker can be used to determine the preference order relationship between different options, which not only ensures the validity of the data but also fully reflects the real state of the decision maker's indecision.The high-quality development of the agricultural economy in Guizhou province involves a variety of complex factors and indicators that interact with each other and are difficult to analyse accurately and quantitatively.The use of hesitant fuzzy linguistic term sets is more comprehensive in considering the impact of various factors on the development of Guizhou's agricultural economy. In addition, this method can compensate for incomplete data to a certain extent and is more flexible and easy to use.

In view of this, this paper selects 17 indicators from four aspects, including the optimization of agricultural economy structure, the level of mechanization of agricultural economy, the green development of agricultural economy, and the opening and sharing of agricultural economy, to construct an evaluation system for the level of high-quality development of agricultural economy in Guizhou's prefecture-level cities. The original data of the indicators of nine prefecture-level cities in Guizhou Province from 2017-2021 were also selected to empirically measure the quality of agricultural economic development of cities in Guizhou Province by applying the hesitant fuzzy language PROMETHEE method, and then put forward relevant policy recommendations.

## 2. Research Methodology

### 2.1. Pre-requisite knowledge

Definition 1 [12] Let $S=\{s_g|g=0,1,\ldots,\tau\}$ be the set of linguistic terms and $a_i\in A(i=1,2,\ldots,N)$, the mathematical form of the set of hesitant fuzzy languages $H_S$ on A be: $H_S=\{<a_i,h_s(a_i)>\mid a_i\in A\}$. Where, function $h_S(a_i): A\rightarrow S$ refers to the possible affiliation of an element $a_i\in A$ mapping to a set $X\supset S$, $h_S(a_i)$ is a sequence of consecutive possible values in the set $S$ of linguistic terms, and $h_S(a_i)=\{s_{\varphi_l}(a_i)\mid s_{\varphi_l}(a_i)\in S, l=1,\cdots,L(a_i)\}$, $\varphi_l\in\{0,1,\cdots,\tau\}$ is the subscript of the linguistic term $s_{\varphi_l}(a_i)$, $L(a_i)$ is the number of linguistic terms in $h_S(a_i)$ .For simplicity, $h_S(a_i)$ is called the number of hesitant fuzzy languages, and $H_S$ is the set of all hesitant fuzzy languages on the set $S$ of linguistic terms.

Definition 2 [12] Let $E_{G_H}$ be the function that converts the linguistic expressions $ll\in S_{ll}$ generated by a text free g rammar $G_H$ into hesitant fuzzy $H_S$, and $S$ be the set of linguistic terms employed by the grammar $G_H$.$S_{ll}$ is set of all e xpressions generated by the grammar $G_H$, then the linguistic expressions generated by the generative rules of the gra mmar $G_H$ can be converted into the set of hesitant fuzzy languages by the conversion formula $E_{G_H}: S_{ll}\rightarrow H_S$, where:

$E_{G_H}(s_t)=\{s_t\mid s_t\in S\}$; $E_{G_H}$(at most $s_m$)$=\{s_t\mid s_t\in S$ and $s_t\le s_m\}$; $E_{G_H}$(less than $s_m$)$=\{s_t\mid s_t\in S$ and $s_t<s_m\}$; $E_{G_H}$(at least $s_m$)$=\{s_t\mid s_t\in S$ and $s_t\ge s_m\}$; $E_{G_H}$(more than $s_m$)$=\{s_t\mid s_t\in S$ and $s_t>s_m\}$; $E_{G_H}$(between $s_m$ and $s_n$)$=\{s_t\mid s_t\in S$ and $s_m\le s_t\le s_n\}$;

In some cases, for two different hesitant fuzzy linguistic numbers, the number of linguistic terms they contain may be different. In order to perform the correct operation for two hesitant fuzzy linguistic numbers, this paper refers to the method in the literature [14] to increase the language for hesitant fuzzy linguistic numbers with fewer linguistic terms. Let $b=\{b_l\mid l=1,2,\cdots,\#b\}$ be the number of hesitant fuzzy languages, $\#b$ be the number of linguistic terms in $b$, let $b^+$ and $b^-$ be the largest and smallest linguistic terms in $b$ respectively, and $\xi$ ($0\leqslant\xi\leqslant1$) be an optimization parameter, then the linguistic term $b$ added to the less hesitant fuzzy language number is $b=\xi b^+\oplus(1-\xi)b^-$, which is taken as $\xi=0.5$ in this paper.

Definition 3 [12] The positive and negative ideal solutions of the hesitant fuzzy language are: $A^+=\{h_S^{1+},h_S^{2+},\cdots,h_S^{n+}\}$ and $A^-=\{h_S^{1-},h_S^{2-},\cdots,h_S^{n-}\}$, where ($j=1,2,\ldots,n$),

$$h_S^{j+}=\begin{cases}\max\limits_{i=1,2,\ldots,m} h_S^{ij+}=\max\limits_{\substack{i=1,2,\ldots,m\\ l=1,\ldots,\#h_S^{ij}}}\left\{s_{\delta_l^{ij}}\right\}, \text{for revenue indicators}\\[2ex] \min\limits_{i=1,2,\ldots,m} h_S^{ij-}=\min\limits_{\substack{i=1,2,\ldots,m\\ l=1,\ldots,\#h_S^{ij}}}\left\{s_{\delta_l^{ij}}\right\}, \text{for cost indicators}\end{cases}\tag{1}$$

$$h_S^{j-}=\begin{cases}\max\limits_{i=1,2,\ldots,m} h_S^{ij+}=\max\limits_{\substack{i=1,2,\ldots,m\\ l=1,\ldots,\#h_S^{ij}}}\left\{s_{\delta_l^{ij}}\right\}, \textit{for}\text{ cost indicators}\\[2ex] \min\limits_{i=1,2,\ldots,m} h_S^{ij-}=\min\limits_{\substack{i=1,2,\ldots,m\\ l=1,\ldots,\#h_S^{ij}}}\left\{s_{\delta_l^{ij}}\right\}, \text{for revenue indicators}\end{cases}\tag{2}$$

### 2.2. Hesitant fuzzy linguistic PROMETHEE method

Hesitant fuzzy languages allow decision makers to qualitatively describe objective things in the presence of incomplete information and indecision between several different linguistic messages, etc. They meet the needs of realistic decision making processes, as some decision problems cannot be measured quantitatively but only evaluated qualitatively. The algorithmic steps of the hesitant fuzzy linguistic PROMETHEE method based on an improved linear criterion preference function are given below [12]:

Step 1: Define a multi-attribute decision problem according to the decision needs, determine $A=\{a_1, a_2, \dots a_\mathrm{m}\}$ as the set of solutions, $C=\{C_1, C_2, \dots C_\mathrm{n}\}$ as the set of indicators, and the set formed by the weights of each indicator as $W=\{W_1, W_2, \dots W_n\}$, where $0 \leq W_j \leq 1$ and $\sum_{j=1}^{n} W_j = 1$.

Step 2: Generate linguistic expressions $ll$ for the above decision problem using linguistic expressions to give a qualitative assessment of the performance of each option $A_i$ under each attribute $C_j$.

Step 3: Transform the linguistic expression $ll$ into a hesitant fuzzy language set $H_S^{IJ}$ according to Definition 2. Also, new linguistic terms are added in order to perform the correct operation on the two hesitant fuzzy linguistic numbers, so that each hesitant fuzzy linguistic number contains the same number of linguistic terms.

Step 4: Calculate the individual attribute weights to form a collection of attribute weights $\mathrm{W}=\{W_1, W_2, \dots W_n\}$, where $0 \leqslant W_j \leqslant 1$, and $\sum_{j=1}^{n} W_j = 1$. This article introduces the entropy weight method to calculate attribute weights here. The entropy weight method to determine the attribute weight can be roughly divided into the following two steps [12]:

(1) For a multi-attribute decision matrix $(h_{ij})_{n \times m}$ with n attributes for m scenarios, calculate the entropy value of the jth indicator:

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} \left(\varepsilon \ln \varepsilon\right), \sum_{i=1}^{n} h_{ij} \neq 0, j = 1, 2, \dots, m \tag{3}$$

Of which $\varepsilon = h_{ij} \left(\sum_{i=1}^{n} h_{ij}\right)^{-1}$,when $\varepsilon = 0, ln\varepsilon = 0$.

(2) Based on the results of the calculation of the entropy value, the weights of each attribute are calculated:

$$w_j = 1 - e_j \Big/ \sum_{j=1}^{n} \left(1 - e_j\right), j = 1, 2, \dots, m \tag{4}$$

Step 5: Determine the preference function. The literature [12] gives six forms of preference functions, each with corresponding meanings and conditions of applicability, and decision makers can choose according to the actual problems they face or construct their own preference functions. This paper draws on the improved preference functions proposed in the literature [12], and the specific improved functions are expressed as:

$$P_j\left(a_i, a_k\right) = \begin{cases} 0, & d_j\left(a_i, a_k\right) \leq 0 \\ \dfrac{d_j\left(a_i, a_k\right)}{\theta d_j\left(A_j^+, A_j^-\right)} & 0 < d_j\left(a_i, a_k\right) \leq \theta d_j\left(A_j^+, A_j^-\right) \\ 1, & d_j\left(a_i, a_k\right) > \theta d_j\left(A_j^+, A_j^-\right) \end{cases} \tag{5}$$

where $d_j(a_i, a_k)$ denotes the departure from any two solutions $a_i$ and $a_k$ under the attribute $X_j$, i.e. $d_j(a_i, a_k) = \sigma_s^{ij} - \sigma_s^{kj} (i,k=1,2,3,\dots n)$. $\sigma_s^{ij}$ is the sum of the number of all hesitant fuzzy languages in a hesitant fuzzy language set $\sigma_s^{ij} - \sigma_s^{kj}$, and similarly $d_j(A_j^+, A_j^-)$ denotes the deviation of a positive ideal solution from a negative ideal solution. In addition $0 < \theta < 1$, the decision maker has the autonomy to choose the value of $\theta$ according to the actual situation of the decision problem and his or her subjective preferences.

Step 6: Calculate the priority index. In order to obtain the overall rank above relationship between the objectives, the priority index $\pi\left(a_i, a_k\right)$ of each objective needs to be calculated. The closer the priority index is to 1, the better the solution is.

$$\pi\left(a_i, a_k\right) = \sum_{r=1}^{n} w_j P_j\left(a_i, a_k\right) \tag{6}$$

Where $j = 1, 2, \dots, n; i, k = 1, 2, \dots, m$ .

Step 7: Calculate the flow rate.

Outflow: $\phi^+\left(a_i\right) = \sum_{r=1}^{n} \pi\left(a_i, a_k\right) = \sum_{j=1}^{m} \sum_{r=1}^{n} w_j P_j\left(a_i, a_k\right) \quad (7)$

Inflow: $\phi^-\left(a_i\right)=\sum_{r=1}^{n}\pi\left(a_k,a_i\right)=\sum_{j=1}^{m}\sum_{r=1}^{n}w_jP_j\left(a_k,a_i\right)$ (8)

Where $j=1,2,...,n;i,k=1,2,...,m$ .

Step 8: Calculate the net flow.

$$\phi\left(a_i\right)=\phi^+\left(a_i\right)-\phi^-\left(a_i\right) \tag{9}$$

The larger the number $\phi\left(a_i\right)$ is, the higher the superiority of the solution, and the smaller the number $\phi\left(a_i\right)$ is, the lower the superiority of the solution, resulting in a ranking of all solutions.

## 3. Empirical analysis

### *3.1. Indicator system construction*

Based on the research results of many scholars [1,2], following the principles of scientific, objective, systematic and relative independence in the selection of indicators. The evaluation index system for the high-quality development of the agricultural economy, which includes 4 primary indicators and 17 secondary indicators, was constructed by combining the current situation of the development of the agricultural economy in Guizhou Province. As shown in Table 1.

Table 1 Evaluation index system for high-quality agricultural economic development of prefecture-level cities in Guizhou

| Target level | Guideline level | Factor level | Unit | Indicator weights① |
|---|---|---|---|---|
| High quality development level of the agricultural economy | optimization of the structure of agricultural economy | Total agricultural output | billion | 0.0631 |
| | | Primary industry added value | billion | 0.0662 |
| | | Food yield | % | 0.0482 |
| | | Agricultural workers | 10000 people | 0.0571 |
| | | Proportion of investment in agriculture | % | 0.0243 |
| | mechanization level of agricultural economy | Total power of agricultural machinery | kw | 0.0528 |
| | | Machine-cut area | hectare | 0.1110 |
| | | Machine-sown area | hectare | 0.0515 |
| | | Machine-cultivated area | hectare | 0.0657 |
| | green development of agricultural economy | Fertilizer consumption | ton | 0.0225 |
| | | pesticide usage | ton | 0.0573 |
| | | plastic film consumption | ton | 0.0262 |
| | | Soil erosion control area | acres | 0.0344 |
| | open sharing of agricultural economy | Road mileage | kilometer | 0.0513 |
| | | Number of beds in health centres per 1,000 agricultural population | sheet | 0.0678 |
| | | Per capita living expenditure in rural areas | yuan | 0.0922 |
| | | Per capita disposable income of rural people | yuan | 0.1084 |

Note：①The index weight is calculated by the entropy weight method.

### *3.2. Sample data*

The raw data for the indicators in this article were obtained from the statistical yearbooks of nine prefectures and cities in Guizhou from 2018-2022, the statistical yearbook of Guizhou Province from 2018-2022, the website of the Guizhou Provincial Bureau of Statistics, the Department of Agriculture and Rural Affairs of Guizhou, the websites of the statistical bureaus of nine prefectures and cities in Guizhou and official government websites, and individual missing data were obtained through estimation methods. Due to the large amount of raw data, they are not shown separately in the article.

### 3.3. Empirical Process and Results

The solution set of this paper is nine prefecture-level cities in Guizhou province, and the attribute set is 17 indicators:C=$\{C_1, C_2, C_3, \ldots, C_{17}\}$.The set $S$ of linguistic terms for this 17 attributes can be expressed as $S$=$\{\{s_0\}$=very poor, $\{s_1\}$=poor, $\{s_2\}$=less favourable, $\{s_3\}$=medium, $\{s_4\}$=good, $\{s_5\}$=better, $\{s_6\}$=very good$\}$.

Decision-making experts make a subjective assessment of the quality of agricultural economic development in the nine prefectures and cities of Guizhou, generating a linguistic expression $ll$ , which yields qualitative assessment data for the nine prefectures and cities of Guizhou under 17 attributes. $ll$ is transformed into hesitant fuzzy language $H_S^{IJ}$ according to the conversion function. (the following calculation process takes 2021 data as an example)

Table 2 Matrix of qualitative evaluation of attributes of nine prefecture-level cities in Guizhou in 2021

| | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ | $a_7$ | $a_8$ | $a_9$ |
|---|---|---|---|---|---|---|---|---|---|
| $C_1$ | $\{s_2\}$ | $\{s_2\}$ | $\{s_5, s_6\}$ | $\{s_1, s_2\}$ | $\{s_5, s_6\}$ | $\{s_4\}$ | $\{s_0, s_1\}$ | $\{s_3\}$ | $\{s_3, s_4\}$ |
| $C_2$ | $\{s_2\}$ | $\{s_2\}$ | $\{s_5\}$ | $\{s_1, s_2\}$ | $\{s_5\}$ | $\{s_3, s_4\}$ | $\{s_3\}$ | $\{s_3\}$ | $\{s_3, s_4\}$ |
| $C_3$ | $\{s_4\}$ | $\{s_2, s_3\}$ | $\{s_3\}$ | $\{s_4\}$ | $\{s_5, s_6\}$ | $\{s_4\}$ | $\{s_3\}$ | $\{s_3, s_4\}$ | $\{s_4\}$ |
| $C_4$ | $\{s_0, s_1\}$ | $\{s_1\}$ | $\{s_5\}$ | $\{s_1, s_2\}$ | $\{s_5\}$ | $\{s_2\}$ | $\{s_2\}$ | $\{s_2, s_3\}$ | $\{s_3\}$ |
| $C_5$ | $\{s_2\}$ | $\{s_4, s_5\}$ | $\{s_4\}$ | $\{s_2, s_3\}$ | $\{s_4\}$ | $\{s_3, s_4\}$ | $\{s_3, s_4\}$ | $\{s_2\}$ | $\{s_5, s_6\}$ |
| $C_6$ | $\{s_0, s_1\}$ | $\{s_0\}$ | $\{s_3, s_4\}$ | $\{s_1\}$ | $\{s_5\}$ | $\{s_2\}$ | $\{s_0, s_1\}$ | $\{s_2\}$ | $\{s_2\}$ |
| $C_7$ | $\{s_3\}$ | $\{s_2\}$ | $\{s_6\}$ | $\{s_4, s_5\}$ | $\{s_4, s_5, s_6\}$ | $\{s_2\}$ | $\{s_2\}$ | $\{s_3\}$ | $\{s_2, s_3\}$ |
| $C_8$ | $\{s_4\}$ | $\{s_0\}$ | $\{s_6\}$ | $\{s_5\}$ | $\{s_1\}$ | $\{s_4\}$ | $\{s_1\}$ | $\{s_2, s_3, s_4\}$ | $\{s_3\}$ |
| $C_9$ | $\{s_2\}$ | $\{s_0, s_1\}$ | $\{s_4\}$ | $\{s_2\}$ | $\{s_6\}$ | $\{s_2\}$ | $\{s_0\}$ | $\{s_3\}$ | $\{s_2\}$ |
| $C_{10}$ | $\{s_6\}$ | $\{s_5\}$ | $\{s_1, s_2\}$ | $\{s_5\}$ | $\{s_0\}$ | $\{s_2, s_3\}$ | $\{s_4\}$ | $\{s_3\}$ | $\{s_2\}$ |
| $C_{11}$ | $\{s_4, s_5\}$ | $\{s_6\}$ | $\{s_0, s_1\}$ | $\{s_3, s_4\}$ | $\{s_3\}$ | $\{s_0\}$ | $\{s_2, s_3\}$ | $\{s_0\}$ | $\{s_0, s_1, s_2\}$ |
| $C_{12}$ | $\{s_6\}$ | $\{s_4, s_5, s_6\}$ | $\{s_0, s_1\}$ | $\{s_3\}$ | $\{s_3, s_4\}$ | $\{s_4\}$ | $\{s_5, s_6\}$ | $\{s_2, s_3\}$ | $\{s_0\}$ |
| $C_{13}$ | $\{s_3, s_4, s_5\}$ | $\{s_0, s_1\}$ | $\{s_6\}$ | $\{s_3, s_4\}$ | $\{s_5, s_6\}$ | $\{s_5\}$ | $\{s_4\}$ | $\{s_6\}$ | $\{s_1, s_2\}$ |
| $C_{14}$ | $\{s_1\}$ | $\{s_2\}$ | $\{s_4\}$ | $\{s_2\}$ | $\{s_2, s_3\}$ | $\{s_4, s_5\}$ | $\{s_5\}$ | $\{s_6\}$ | $\{s_3, s_4\}$ |
| $C_{15}$ | $\{s_6\}$ | $\{s_3, s_4\}$ | $\{s_4\}$ | $\{s_3, s_4\}$ | $\{s_3\}$ | $\{s_4\}$ | $\{s_2, s_3\}$ | $\{s_0, s_1\}$ | $\{s_4\}$ |
| $C_{16}$ | $\{s_6\}$ | $\{s_2, s_3\}$ | $\{s_4, s_5\}$ | $\{s_2\}$ | $\{s_1, s_2\}$ | $\{s_3, s_4\}$ | $\{s_3\}$ | $\{s_1\}$ | $\{s_3, s_4\}$ |
| $C_{17}$ | $\{s_5, s_6\}$ | $\{s_3\}$ | $\{s_4, s_5\}$ | $\{s_2, s_3\}$ | $\{s_2, s_3\}$ | $\{s_3\}$ | $\{s_3, s_4\}$ | $\{s_2\}$ | $\{s_3\}$ |

Of the 17 indicators, "fertilizer consumption", "pesticide usage" and "plastic film consumption" are cost indicators, while the rest are revenue indicators. Then the positive ideal solution for determining the hesitant fuzzy language is $A^{+}$=$\{\{S_6\}, \{S_5\}, \{S_6\}, \{S_5\}, \{S_6\}, \{S_5\}, \{S_6\}, \{S_6\}, \{S_6\}, \{S_0\}, \{S_0\}, \{S_0\}, \{S_6\}, \{S_6\}, \{S_6\}, \{S_6\}, \{S_6\}\}$, the negative ideal solution is $A^{-}$=$\{\{S_0\}, \{S_1\}, \{S_2\}, \{S_0\}, \{S_2\}, \{S_0\}, \{S_2\}, \{S_0\}, \{S_0\}, \{S_6\}, \{S_6\}, \{S_6\}, \{S_0\}, \{S_1\}, \{S_0\}, \{S_1\}, \{S_2\}\}$. Calculate the deviation between the positive ideal solution $A^{+}$and the negative ideal solution $A^{-}$of the hesitant fuzzy language, and calculate the degree to which solution $a_i$ ($i$=1,2,..,9) is superior to solution $a_k$ ($k$=1,2,..,9) according to the preference function (based on the need for decision facts and investors' preference for a strictly superior degree, $\theta$ = 0.6 in this paper).The outflows and inflows of each of the nine cities in Guizhou in 2021 are calculated according to equation (7) and equation (8), and the net flows of the cities are derived accordingly.Similarly, the inflows, outflows and net flows of nine cities and regions in Guizhou Province in 2017, 2018, 2019 and 2020 can be calculated. The specific results are shown in Table 3.

Table 3 Net flow of nine prefecture-level cities in Guizhou from 2017-2021

| City | 2017 | 2018 | 2019 | 2020 | 2021 | Average value | Growth rate | Ranking |
|---|---|---|---|---|---|---|---|---|
| Zunyi | 2.9846 | 2.9937 | 3.0954 | 3.8664 | 3.4821 | 3.2844 | 14.29% | 1 |
| Bijie | 2.2374 | 2.1598 | 2.2098 | 2.2507 | 2.4688 | 2.2263 | 9.37% | 2 |
| Guiyang | 1.9240 | 1.8375 | 1.9649 | 1.9837 | 2.1954 | 1.9811 | 12.36% | 3 |
| Qiannan | -0.3685 | -0.3426 | -0.3379 | -0.3227 | -0.3156 | -0.3375 | 16.76% | 4 |
| Anshun | -1.2574 | -1.2403 | -1.2067 | -1.1934 | -1.0481 | -1.1892 | 19.97% | 5 |
| Tongren | -1.5579 | -1.5538 | -1.5366 | -1.4936 | -1.3780 | -1.5039 | 13.06% | 6 |
| Qiandongnan | -1.7638 | -1.6197 | -1.6234 | -1.5662 | -1.5613 | -1.6269 | 12.96% | 7 |
| Liupanshui | -2.5374 | -2.3901 | -2.1673 | -2.2472 | -2.1985 | -2.3081 | 15.42% | 8 |
| Qianxinan | -3.2341 | -3.0627 | -2.9855 | -2.9032 | -2.7908 | -2.9953 | 15.88% | 9 |

As can be seen from Table 3, the top three net flows for the nine cities and municipalities from 2017 to 2021 are Zunyi, Bijie and Guiyang, which belong to the more developed agricultural economy, with Zunyi having the highest average net flow value and an obvious advantage over other prefecture-level cities. Qiannan, Anshun, Tongren, Qiandongnan, Liupanshui and Qianxinan all have net flow values less than zero and are less developed agricultural economies, with Qianxinan having the lowest net flow among the nine prefectures and cities each year and being the prefecture and city with the lowest level of agricultural economic development in Guizhou Province. In addition, the difference between the net flow of the highest and lowest quality cities and states in Guizhou Province each year, indicates that there is a regional imbalance in the overall level of agricultural economic development in Guizhou Province, with the central cities and their surrounding areas having better quality agricultural economic development, while some remote, mountainous and minority-group areas are relatively lagging behind in agricultural economic development.

Over time, the net flows of all nine prefectures and cities in Guizhou have increased significantly, reflecting a trend of growth in the level of agricultural economic development of prefecture-level cities in Guizhou in general between 2017 and 2021. Among them, the net flow value of Anshun City increased by 19.97% in 2021 compared with 2017, ranking first in the province in terms of the increase in the level of high-quality development of the agricultural economy; the net flow value of Qiannan Prefecture increased by 16.76% in 2021 compared with 2017, ranking second in the province in terms of the increase in the level of high-quality development of the agricultural economy; the net flow growth rates of Liupanshui City and Qianxinan Prefecture were at the top of the province, and from the results in Table 3 From the results in Table 3, we can see that the annual agricultural economic quality level of these two cities and municipalities is not as high as that of other cities and municipalities, but their annual development rate is at the forefront of Guizhou Province, indicating that they have great room for development; the agricultural economic development level of Bijie City and Guiyang City was declining between 2017 and 2018, and then the agricultural economic development level of these two cities returned to an upward state in the following years, meanwhile, the net flow of Bijie City The slowest growth rate is probably due to the accelerated urbanisation process, which has led to a decrease in the number of rural labourers in Bijie and has affected agricultural productivity to a certain extent.

## 4. Conclusions and policy recommendations

This paper constructs the following conclusions:

Firstly, spatially, during the sample period, the high-quality development level of agricultural economy in Zunyi, Bijie and Guiyang ranked among the top three in the province, which has great advantages compared with other prefectures and cities. The quality of agricultural economic development in Qiannan Prefecture, Anshun City, Tongren City, Qiandongnan Prefecture and Liupanshui City is relatively low, and the agricultural economic development of Qianxian Prefecture is the most backward, indicating that there is a serious regional imbalance in the agricultural economic development of Guizhou Province, and the agricultural economic development of all prefectures and cities needs to be improved.

Secondly, during the sample period, from 2017 to 2021, there were different degrees of growth in the high-quality development level of agricultural economy in nine prefectures and cities in Guizhou. Among them, Anshun City and Qiannan Prefecture ranked first and second in the province in terms of high-quality agricultural economic development, while Liupanshui City and Qiannan Prefecture, which are cities with poor agricultural economic development quality, are in the forefront of Guizhou Province, indicating that they have great development potential. It reflects the continuous development trend of the quality of agricultural economic development in Guizhou.

According to the above research conclusions, the following policy suggestions are put forward: on the basis of maintaining the existing advantages, Zunyi will further increase its support for agricultural scientific and technological innovation, and achieve sustainable development of agricultural economy; Bijie should use marketing means to promote branded agricultural products, so as to attract more people to engage in agricultural activities; Guiyang should strive to carry out the planting and breeding of high-quality agricultural products with high quality and high standards, and enhance the brand image of agricultural products; Qiannan Autonomous Prefecture should establish a scientific breeding model and management system to improve economic efficiency and help agricultural scientific and technological innovation; Anshun can combine farmhouses, ecological agriculture, etc. with tourism to achieve diversified operation of agriculture; Tongren should promote new planting models suitable for local areas, and realize the intelligent development of agricultural economy; Qiandongnan Autonomous Prefecture can strengthen rural infrastructure construction and provide good material guarantee for agricultural development; Liupanshui should pay more attention to the agricultural economy and expand the sales channels and market scope of agricultural products; Qianxian Autonomous Prefecture can introduce new agricultural technologies to improve the quality and yield of crops.

## Acknowledgements

This research was funded by the Regional Project of National Natural Science Foundation of China, grant number 71861003.

## References

[1] Wang, L., Lv, P., & Jia, J. (2023) "Evaluation of high-quality development of agricultural economy based on entropy value method: A case study of Liaoning Province." *Agricultural Economics* (02):3-6.

[2] Huang, X. Cai, X., & Chu, X. L., et al. (2020) "The construction and evaluation of a high-quality development index for agriculture in China." *China Agricultural Resources and Zoning* (4):124-133.

[3]Zhang W. H., Chen, Y., & Liu J. L. (2023) "Measurement and evaluation of the level of high-quality agricultural development in Guizhou under the new development concept." *Modern Agriculture* 48(01):49-53.

[4]Zhang J. W., Zeng, Z. Q. & Li, G. D. (2022) "Measuring the level of high-quality development of China's agricultural economy and its spatial variation analysis." *World Agriculture* (10):98-110.

[5] Liang, Y. M., & Zhao, J. L. (2021) "Comprehensive evaluation of agricultural economy in southwest China——Based on entropy weight TOPSIS method." *Science Technology and Industry* 21(11):227-232.

[6] Zhang, C. X., & Yang, S. X. (2021) "Comprehensive evaluation and analysis of the economic development level of green agriculture in Anhui Province." *Journal of Suzhou University* 36(08):28-31.

[7]Rodríguez R M, Martínez L, & Herrera F. (2021) "Hesitant fuzzy linguistic term sets for decision making." *IEEE Transactions on Fuzzy Systems* 20(1):109-119.

[8]Shi, H. B., Li, X. Y., & Song, G. (2022) "Evaluation of urban business environment based on hesitation fuzzy set distance measurement." *Journal of Shenyang University of Technology(Social Science Edition)*:1-7.

[9]Li, B. B., & Zhang, M. F. (2023) "Risk assessment of medical data security based on probabilistic hesitation fuzzy set." *Modern Information Technology* 7(06):102-106.

[10]Pan, S. Y., & Gao, Z. F. (2018) "VIKOR advertising scheme decision based on interval hesitation fuzzy set." *Value engineering* 37(09):166-167.

[11]Brans J P, & Vincke P. (1985) "A preference ranking organization method: The PROMETHEE method for MCDM." *Management Science* 31(6): 647-656.

[12] Liao, H. C., Yang, Z., & Xu, Z. S., et al. (2019) "Application of PROMETHE Method of Hesitant Fuzzy Language in Sichuan Wine Brand Evaluation." *Control and Decision-making* 34(12):2727-2736.

[13] Wang, L., Zhou, Y. N., & Zhang, Y. (2017) "Evaluation and Obstacle Analysis of Low-carbon City Development Level Based on Entropy Weight-TOPSIS Method——A Case Study of Tianjin." *science and technology management research* 37(17):239-245.