Drought Risk Assessment of Summer Maize in Kaifeng City based on Fuzzy Comprehensive Evaluation Method

Jianghao Yu

School of Resources and Environment, Henan Polytechnic University, Jiaozuo, Henan 454000, China

Abstract

Taking summer maize in Kaifeng city as an example to evaluate drought risk in Kaifeng city, fuzzy comprehensive analysis method is used, combining entropy weight method and analytic hierarchy process to determine comprehensive weight. The dimension of summer maize growth has the greatest impact on drought risk assessment, while the dimension of maize disaster has the smallest impact. Among the four first-level indicators included in the growth of summer corn, the plant growth height can best reflect the growth of corn, while the grain weight has the weakest impact. By establishing a fuzzy comprehensive evaluation model, a drought risk assessment was conducted for summer corn in Kaifeng City from 1992-2009, The drought in 1992-2002 was relatively severe, The drought degree in 1995 was the most severe,The drought situation in 2003-2007 has slowed down compared to previous years, Drought has a rising trend in 2008-2009.

Keywords

Drought Disaster; Risk Evaluation; Fuzzy Comprehensive Evaluation; Entropy Weight Method; Analytic Hierarchy Process; Kaifeng City.

1. Introduction

Drought is currently one of the major natural disasters in the world, characterized by large impact, long duration, and high frequency of occurrence. It will have a direct impact on the social economy, and its direct harm will cause a reduction in the production of agricultural and animal husbandry industries, which will have a significant impact on the lives and economies of farmers.China is also a country where drought disasters occur frequently.

In the process of agricultural production, the losses caused by meteorological disasters are often enormous, so it is necessary to pay attention to preventing meteorological disasters in production[1]. Climate change can change environmental conditions in agricultural production, especially in extreme weather; Climate will also change the resilience and vulnerability of agricultural systems, creating new features of agricultural disasters.Due to the fact that disasters cannot be prevented by humans, drought risk assessment of the region can only be carried out using multiple disaster indicators of drought disasters on crops in previous years, in order to prevent and control the negative impact of drought disasters and reduce socio-economic losses[2]. Therefore, drought risk assessment is of great significance for the growth and development of crops.

Domestic scholars such as Wang Dongfang believe that agricultural drought risk is a probability of possibility, specifically referring to the probability of losses caused by drought disasters in the agricultural production and farmers' lives in a region[3]; Zhu Yeyu and others believe that agricultural drought risk is caused by the interaction between drought intensity, drought frequency, and social, economic, and environmental vulnerabilities in agriculture[4]. Dhakar et al. conducted a

ISSN: 2414-1895
DOI: 10.6919/ICJE.202305_9(5).0026

comprehensive and systematic research on the specific content and steps involved in drought disaster risk management[5]. Ismail et al. used statistical methods to analyze the standardized precipitation index (SPI) and corn yield in Nebraska, USA, and further evaluated the risk of agricultural drought on corn in Nebraska [6]; Frank et al. used the meteorological drought index SPI to determine the intensity and frequency of drought, and based on this, constructed a drought risk index, thereby achieving the classification and spatial distribution of drought risk levels[7]. Many scholars have systematically studied the evolution of drought disasters in selected regions from different perspectives, and have achieved many practical and valuable results.

This article takes the summer corn in Kaifeng City as an example to conduct drought risk assessment in the area of Kaifeng City, and use entropy weight method and analytic hierarchy process to determine the comprehensive weight value of each index, then establish a drought risk evaluation system in Kaifeng City[8].By analyzing the characteristics of various factors in Kaifeng City through a fuzzy comprehensive evaluation model, the weight and membership vector of each indicator are determined, and a fuzzy evaluation matrix is obtained; Finally, the obtained fuzzy evaluation matrix and the full vector of the indicators are fuzzy operated to obtain the fuzzy comprehensive evaluation results of drought for summer maize in Kaifeng City.

2. Research Method

Fuzzy comprehensive evaluation is a method of comprehensive evaluation based on fuzzy mathematics, which applies the synthesis principle of fuzzy relations to quantify factors with unclear boundaries and difficult to quantify, and evaluates the status of the evaluated objects through multiple factors.

(1)Build indicator set X

Indicator set refers to a collection of multiple attributes of an evaluation object, which can comprehensively express the evaluation object. If n elements are selected from the evaluated object, x_i represents the ith indicator in the indicator set, and the indicator set X represents:$X=[X_1,X_2 \dots X_n]$.

(2)Build comment set V

A comment set is a collection that contains all possible situations among the evaluation objects. If the evaluated object has n evaluation results, then V_j represents the result of the j th evaluation in the comment set, and V represents the result of the jth evaluation in the comment set:$V=[\mu_1,\mu_2 \dots \mu_n]$, and there is a score set corresponding to the comment set V $G=[g_1,g_2 \dots g_n]$.

(3)Establish a weight set

The importance of each indicator selected in the corresponding system varies. Therefore, we will assign weight values w_i to each indicator factor X_i, and then combine these weight values into a set W, which is called a weight set: $W=[w_1,w_2 \dots w_n]$. Generally speaking, each weight value w_i is greater than or equal to 0, jus:$w_1+w_2+\dots+w_n=1$.

(4)Building a single indicator evaluation matrix

In order to determine the degree of membership of the evaluated object rating set V, this article starts from a single indicator to evaluate it, which is called single indicator fuzzy evaluation. After performing a hierarchical fuzzy subset, the next step is to quantify each index x_i of the evaluated object. When determining the membership of each subset of the evaluated object, a single factor is used to determine the fuzzy relationship matrix, and a single factor fuzzy evaluation matrix is obtained $R=(r_{ij})_{m\times n}$, It is composed of n single factor evaluation matrices on V, where:

$$R=\begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ \dots & \dots & \dots & \dots \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix}$$

(5)Comprehensive evaluation

The importance of evaluation indicators varies depending on different influencing factors. Therefore, in order to comprehensively consider the importance of each indicator to the performance of the evaluation object, it is necessary to establish a fuzzy vector of the weight set based on the weight value assigned to each indicator during the evaluation $W=[w_1, w_2 \ldots w_n]$, where w_i is the weight value of the ith indicator, indicating the impact of this factor on the evaluation object. The fuzzy set on V obtained by R transformation:

$$B' = W \times R = \begin{bmatrix} w_1 & w_2 & \ldots & w_m \end{bmatrix} \times \begin{bmatrix} r_{11} & r_{12} & \ldots & r_{1n} \\ r_{21} & r_{22} & \ldots & r_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ r_{m1} & r_{m2} & \ldots & r_{mn} \end{bmatrix} = \begin{bmatrix} b_1 & b_2 & \ldots & b_n \end{bmatrix}$$

Due to the influence of many factors, when evaluating comprehensively in a more complex system, more influencing factors need to be considered. Therefore, this article adopts multi-level fuzzy comprehensive evaluation. Multilevel fuzzy comprehensive evaluation requires a first level fuzzy comprehensive evaluation starting from the lowest level factors, and then moving up to the highest level factors in order to ultimately obtain the overall desired fuzzy comprehensive evaluation results. The required formula for Level 2 fuzzy evaluation is as follows:

$$B = W \times B' = W \times \begin{bmatrix} B_1 \\ B_2 \\ \ldots \\ B_S \end{bmatrix} = W \times \begin{bmatrix} W_1 \times R_1 \\ W_2 \times R_2 \\ \ldots \\ W_S \times R_S \end{bmatrix} = \begin{bmatrix} b_1 & b_2 & \cdots & b_m \end{bmatrix}$$

During the evaluation process, a hierarchical structure is established based on the established evaluation indicators, and a fuzzy comprehensive evaluation is conducted from the lowest level indicators up to the highest level indicators in order. By analogy, a multi-level comprehensive evaluation formula can be obtained. Referring to the theory of fuzzy mathematics, when conducting risk analysis for drought in Kaifeng City, due to the many factors considered, a comprehensive score E was obtained based on the weighted average principle. Details are as follows:

$$E = B \times G^T = \begin{bmatrix} b_1 & b_2 & \cdots & b_n \end{bmatrix} \times \begin{bmatrix} g_1 \\ g_2 \\ \vdots \\ g_n \end{bmatrix}$$

This model is a weighted average type, which is very stable during the comprehensive evaluation process and does not lose any evaluation factors. It can clearly reflect the role of weights, fully utilize the information of R, and consider the impact of different evaluation indicators on the overall evaluation based on their weight values. It is suitable for situations where the comprehensive degree of the evaluated object is relatively high [9].

3. Drought Risk Assessment of Summer Maize in Kaifeng City

3.1 Overview of the Research Area

Kaifeng City is located in the hinterland of North China Plain, east of Henan Province, and on the south bank of the lower Yellow River. Affected by the terrain and monsoon, Kaifeng has a temperate monsoon climate, characterized by cold and dry winter, dry and windy spring, and moderate autumn rainfall. Rainfall throughout the year is concentrated in summer, but the rainfall in summer is also not ideal. Moreover, Kaifeng City is located to the south of the Yellow River levee, and there are no large rivers, which makes the drought environment and disaster causing factors in Kaifeng City relatively high risk, especially in July, August, and September.

3.2 Establishment of Indicator System

In the risk assessment of summer maize drought disaster in Kaifeng City, an indicator system was established from three dimensions: summer maize growth X_1, soil moisture X_2 at different depths, and maize disaster X_3, and corresponding indicators were selected to standardize the indicator data

Volume 9 Issue 5, 2023
DOI: 10.6919/ICJE.202305_9(5).0026

one by one. In selecting indicators for each dimension, the selection of evaluation indicators should be based on the following principles:

(1) The principle of independence of the evaluation index system;

(2) The quantifiable principle of the evaluation index system;

(3) The representative principle of the evaluation index system;

(4) The principle of combining social and natural factors;

(5) The reliability principle of evaluation index data.

3.2.1 Selection of Growth Index for Summer Maize

Drought and flood disasters occur frequently during the growth stage of summer maize, with the main impact of drought and the widest scope of impact. Therefore, it is reliable to reflect the risk of drought disasters through research on the growth of summer maize.

In this paper, the plant growth height x_{11} and trilobal stage (jointing) date x_{12} were selected for comparison during the same period in mid July; The four indicators of grain weight x_{13} and actual yield x_{14} per mu at maturity were selected to evaluate the drought risk in Kaifeng area.

3.2.2 Selection of Soil Moisture Index at Different Depths

Soil moisture is the soil moisture content, which determines the water supply of crops. If the soil humidity is too low, it will form soil drought, which will affect the growth and development of crops, thereby reducing the yield and quality of crops; High soil humidity can worsen soil aeration, affect soil microbial activity, and hinder the respiration, growth, and life activities of crop roots, thereby affecting the normal growth of crops[10].

In the text, select three indicators: 10cm soil relative humidity x_{21}, 20cm soil relative humidity x_{22}, and 50cm soil relative humidity x_{23} in the middle of July to reflect the drought situation.

3.2.3 Selection of Indicators for Maize Disaster Situation

Selection of indicators for maize disaster situation Drought disasters occur frequently and are difficult to control, resulting in increasing losses of life and property to human society. Selecting two indicators, namely, the affected area of summer corn x_{31} and the affected percentage x_{32}, can intuitively understand the drought situation in Kaifeng area.

3.2.4 Structure Chart of Risk Assessment Indicators for Drought Disasters

Based on the growth situation of summer corn, soil moisture at different depths, and the disaster situation of corn selected in this article, a drought risk evaluation index system was established to evaluate the degree of drought risk.

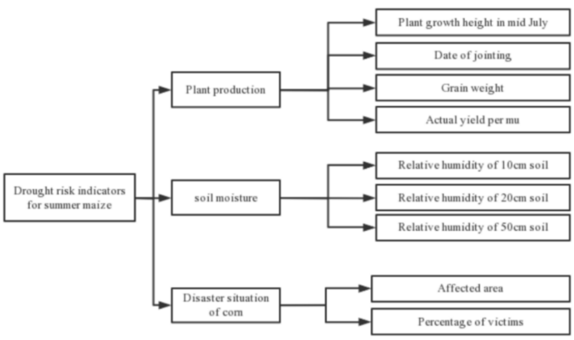

Figure 1. Structure Chart of Drought Risk Assessment Indicators

3.3 Create a Comment Set

Referring to the "Meteorological Drought Rating" document, the selected evaluation set is $V=[v_1, v_2, v_3, v_4]$=[Extreme Drought, Severe Drought, Moderate Drought, Mild Drought]. The corresponding evaluation set is $G=[g_1, g_2, g_3, g_4]$, and the evaluation value of summer corn drought risk in Kaifeng area is determined as G=[81,61,31,10] according to the "Meteorological Drought Rating" [11] document, The evaluation criteria are shown in the table below.

Table 1. Standard Table of Comment Set

Evaluation criterion	[100,81]	[80,61]	[60,31]	[30,10]
Drought Assessment of Summer Maize	Extreme drought	Severe Drought	Moderate Drought	Mild Drought

3.4 Determination of Index Weights for Drought Risk Assessment of Summer Maize

This article selects 18 years of indicator data from 1992 to 2009, and determines the weight. This article first uses the entropy weight method to determine the objective weight and the analytic hierarchy process to determine the subjective weight. The subjective weight often represents the relative importance between evaluation indicators. The objective weight is obtained through mathematical calculation based on the actual value of the indicator, which mostly reflects the degree of differentiation between indicator data. Then, through the obtained objective weight and subjective weight, the comprehensive weight is determined using the set average method[12].

3.4.1 Determination of Objective Weight by Entropy Weight Method

The entropy weight method belongs to an objective weighting method. In practical use, this method solves the entropy weight of each index based on its degree of variation, and uses information entropy to calculate the entropy weight of each index. The index weight is calculated and modified by entropy weight, thereby obtaining the objective weight of the index. The process is as follows:

(1)The set evaluation object has m, and the total number of indicators included in the evaluation system is n, expressed as $X=(x_{ij})_{m\times n}$; (i=1,2,⋯m; j=1,2,⋯n). And establish a unified and standardized processing judgment matrix to obtain a relative membership matrix: $R=(r_{ij})_{m\times n}$; (i=1,2⋯m; j=1,2⋯n).

The larger the calculated value of the positive evaluation indicators (x_{12}, x_{31}, x_{32}), the drier the evaluation will be. The standardization of such evaluation indicators can be calculated using the following formula:

$$r_{ij}=\frac{x_{ij}-(x_{ij})_{\min}}{(x_{ij})_{\max}-(x_{ij})_{\min}} \tag{1}$$

The smaller the calculation result of negative evaluation indicators (x_{11}, x_{13}, x_{14}, x_{21}, x_{22}, x_{23}), the drier the evaluation will be. The standardization treatment of such evaluation indicators can be calculated using the following formula:

$$r_{ij}=\frac{(x_{ij})_{\max}-x_{ij}}{(x_{ij})_{\max}-(x_{ij})_{\min}} \tag{2}$$

Where: r_{ij} is the indicator value obtained after normalization; $(x_{ij})_{max}$ and $(x_{ij})_{min}$ are the maximum and minimum values of the same indicator data within the selected number of years.

(2)Combining the specific meaning of the entropy value of the selected evaluation index, the entropy value of each evaluation index is calculated according to the following formula:

$$f_{ij}=\frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}} \tag{3}$$

$$H_i=-\frac{\sum_{j=1}^{n} f_{ij}\ln f_{ij}}{\ln n} \tag{4}$$

ISSN: 2414-1895 DOI: 10.6919/ICJE.202305_9(5).0026

Where: H_i is the entropy value obtained by the ith evaluation index among the evaluation objects; F_{ij} is the weight value of the i-th index of the jth selected evaluation object in the evaluation; The value of n depends on the number of indicators for each dimension.

Table 2. Table of entropy Values of Level I Evaluation Indicators

Plant growth height during the same period in mid July (cm)	1.929
Date of jointing (July)	1.958
Grain weight (0.1g)	1.888
Actual yield per mu (kg)	1.921
Relative humidity of 10cm soil (1%)	2.415
Relative humidity of 20cm soil (1%)	2.443
Relative humidity of 50cm soil (1%)	2.421
Percentage of victims in July (%)	3.551
Affected area in July(10000 mu)	3.516

Table 3. Entropy Value Table of Secondary Evaluation Indicators

Plant growth	Soil moisture	Disaster situation of corn
7.696	7.278	7.067

(3)According to the above calculation results, the entropy weight W can be calculated for each evaluation index, and the formula is as follows:

$$\omega_i^* = \frac{1 - H_i}{\sum_{i=1}^{m} (1 - H_i)} \tag{5}$$

Where: ω* Is the entropy weight of each evaluation index, with a value range of 0 to 1. The sum of their entropy weights for all evaluation indexes is 1.

Table 4. Detailed Table of Objective Weights

Criterion layer	Objective weight	Indicator layer	Objective weight
Plant growth	0.352	Plant growth height during the same period in mid July	0.251
		Comparison of jointing dates	0.259
		Grain weight	0.241
		Actual yield per mu	0.249
Soil moisture	0.332	Relative humidity of 10cm soil	0.331
		Relative humidity of 20cm soil	0.337
		Relative humidity of 50cm soil	0.332
Disaster situation of corn	0.318	Affected area	0.503
		Percentage of victims	0.497

 Volume 9 Issue 5, 2023
DOI: 10.6919/ICJE.202305_9(5).0026

3.4.2 Determining Subjective Weights through Analytic Hierarchy Process

Analytic Hierarchy Process (AHP), also known as AHP, was proposed by American scholar Saatye in the 1970s. Analytic Hierarchy Process (AHP) divides the evaluation system into three layers, and uses the importance of each layer to compare and determine the weight of each index. It has considerable subjectivity[13]. The specific steps are as follows:

(1)A comparison matrix is constructed using a 1-9 scale method for the importance of the primary and secondary indicators of the criteria layer. The criteria for the established comparison matrix are based on the following metrics:

Table 5. Judgment Matrix Scaling Criteria

Scale	Meaning
$X_{ij}=1$	Element i and element j have the same importance to the factors at the upper level
$X_{ij}=3$	Element i is slightly more important than element j
$X_{ij}=5$	Element i is more important than element j
$X_{ij}=7$	Element i is much more important than element j
$X_{ij}=9$	Element i is more important than element j
$X_{ij}=2, 4, 6, 8$	Median of the above adjacent judgments

(2) In this paper, we establish a positive and negative judgment matrix for corn growth, soil moisture, and corn disaster conditions, and use the eigenvector method to solve them. Finally, we are conducting a consistency test, because using the analytic hierarchy process to determine the subjectivity of the eigenvector P corresponding to the non zero weight vector of the consistent matrix in the normalized vector; However, for a non-uniform matrix weight vector W, the characteristic root is satisfied λ_{max} characteristic vector of max still needs to be checked for consistency according to the following formula [14]:

$$\lambda_{\max} = \frac{\sum (XW)}{nW} \tag{6}$$

$$C_I = \frac{\lambda_{\max} - N}{n-1} \tag{7}$$

$$C_R = {C_I}/{R_1} \tag{8}$$

In the formula, C_I is a consistency indicator, and the closer the result is to zero, the higher the degree of consistency will be; R_1 is a random consistency indicator, which is a constant and can be queried in Table 9 based on the order; C_R is a ratio. When the calculated consistency ratio $C_R \leq 0.1$, it is considered that the judgment matrix has good consistency. If the resulting $C_R > 0.1$, it indicates that to maintain a significant level, it is necessary to adjust the comparison matrix. Introducing B_i (i=1,2,3,4) as the judgment matrix of the indicator layer, the weight is obtained as ω_i' . The indicator weight of the indicator layer is ω' .

Table 6. Table of Average Random Consistency Indicators

Order	1	2	3	4	5	6
R_I	0	0	0.58	0.9	1.12	1.24

(3)According to the requirements, establish a comparison matrix between the first level indicators and the second level indicators and conduct inspections. The details are shown in the table below.

Table 7. X_{1j} Consistency Inspection Table

λ_{max}	C_I	C_R	Uniformity
4.088	0.029	0.033	√

Table 8. X_{2j} Consistency Inspection Table

λ_{max}	C_I	C_R	Uniformity
3.013	0.007	0.012	√

Table 9. X_{3j} Consistency Inspection Table

λ_{max}	CI	CR	Uniformity
2.000	0	0	√

Table 10. Consistency Inspection Table for Level II Index X

λ_{max}	CI	CR	Uniformity
3.086	0.034	0.059	√

(4)After sorting out the above results, the following table is obtained.

Table 11. Detailed Table of Subjective Weights

Criterion layer	Objective weight	Indicator layer	Subjective weight
Plant growth	0.724	Plant growth height during the same period in mid July	0.603
		Comparison of jointing dates	0.243
		Grain weight	0.050
		Actual yield per mu	0.104
Soil moisture	0.083	Relative humidity of 10cm soil	0.656
		Relative humidity of 20cm soil	0.233
		Relative humidity of 50cm soil	0.111
Disaster situation of corn	0.193	Affected area	0.667
		Percentage of victims	0.333

3.4.3 Determination of Comprehensive Weight

Entropy weight method and analytic hierarchy process have their respective advantages and disadvantages in determining the weight. Although the entropy weight method has the advantages of not being affected by subjective evaluations, the weight of the obtained indicators will vary with the changes in the original data, and the indicator weight depends on the sample, which does not fully reflect the importance of each indicator. Analytic Hierarchy Process (AHP) can fully absorb the experience and knowledge of experts and reflect the importance of various indicators, but its subjective randomness cannot be avoided. Therefore, if a single method is used to determine the weight of indicators, it may produce a certain deviation in the final evaluation results.

Entropy-AHP method is an improved method that integrates the indicator weights obtained by the two methods into a new set of indicator weights, and combines expert determination weights with

ISSN: 2414-1895 DOI: 10.6919/ICJE.202305_9(5).0026

entropy weight method. It combines the characteristics of subjective and objective weighting methods to improve the accuracy of the weights. When evaluating the evaluation object, it can greatly improve the accuracy of its research results. The calculation formula is as follows:

$$(\omega_i)_{1\times n} = \left(\omega_i^* \omega_i^{'} / \sum_{i=1}^{n} \omega_i^* \omega_i^{'} \right) \quad (9)$$

Where: ω_i is the comprehensive weight value based on entropy weight method and analytic hierarchy process.

Table 12. Comprehensive Weight Table

Criterion layer	Objective weight	Indicator layer	Comprehensive weight
Plant growth	0.739	Plant growth height during the same period in mid July	0.604
		Comparison of jointing dates	0.249
		Grain weight	0.049
		Actual yield per mu	0.098
Soil moisture	0.079	Relative humidity of 10cm soil	0.650
		Relative humidity of 20cm soil	0.232
		Relative humidity of 50cm soil	0.118
Disaster situation of corn	0.182	Affected area	0.665
		Percentage of victims	0.335

3.5 Determination of Drought Risk Membership Matrix for Summer Maize

3.5.1 Grading of Indicator Factors

Refer to the meteorological standard "Risk Assessment Method for Drought Hazards in Maize" [15] to objectively and accurately evaluate the drought disaster in Kaifeng, taking summer corn as an example. The drought severity is divided into four levels as follows: extreme drought, severe drought, moderate drought, and mild drought. The grading criteria are as follows.

Table 13. Risk Assessment Criteria for Summer Maize Drought in Kaifeng District

Evaluating indicator	V_1 Extreme drought	V_2 Severe drought	V_3 Moderate drought	V_4 Light drought
Plant height	<45	45-96	96-132	>132
Date of jointing	>13	9-13	5-9	<5
Grain weight	<2.7	2.7-2.9	2.9-3.2	>3.2
Per mu yield	<358	358-387	387-448	>448
Relative humidity of 10cm soil	<35	35-50	50-68	>68
Relative humidity of 20cm soil	<41	41-56	56-74	>74
Relative humidity of 50cm soil	<47	47-62	62-81	>81
Percentage of victims	>80	60-80	25-60	<25
Affected area	>3.5	2.5-3.5	1-2.5	<1

Volume 9 Issue 5, 2023
DOI: 10.6919/ICJE.202305_9(5).0026

3.5.2 Construction of Single Indicator Evaluation Matrix

The evaluation set for drought risk assessment levels in Kaifeng City is V_1, V_2, V_3, V_4. Among the nine selected indicators, plant height, grain weight, mu yield, 10cm soil moisture, 20cm soil moisture, and 50cm soil moisture belong to negative evaluation indicators (x_{11}, x_{13}, x_{14}, x_{21}, x_{22}, x_{23}), that is, the smaller the value, the more severe the drought degree is. The jointing date, affected area, and affected percentage belong to positive evaluation indicators (x_{12}, x_{31}, x_{32}), That is, the greater the numerical value, the more severe the drought. Calculate according to the following membership matrix formula.

$$V_1=\begin{cases}1 & (x<x_1)\\ \dfrac{x-x_1}{x_2-x_1} & (x_1<x<x_2)\\ 0 & (x>x_2)\end{cases} \tag{10}$$

$$V_2=\begin{cases}1-V_1 & (x_1<x<x_2)\\ \dfrac{x-x_2}{x_3-x_2} & (x_2<x<x_3)\\ 0 & (x>x_3)\end{cases} \tag{11}$$

$$V_3=\begin{cases}1-V_2 & (x_2<x<x_3)\\ \dfrac{x-x_3}{x_4-x_3} & (x_3<x<x_4)\\ 0 & (x>x_4)\end{cases} \tag{12}$$

$$V_4=\begin{cases}1-V_3 & (x_3<x<x_4)\\ 1 & (x>x_4)\end{cases} \tag{13}$$

The x_1, x_2, x_3, x_4 in the above V_1, V_2, V_3, V_4 calculation formulas are the boundary values in the Kaifeng City Area Summer Maize Drought Risk Assessment Standard Table. It is specified that x_1, x_2, x_3, x_4 should all select the boundary values with small values.

3.6 Fuzzy Comprehensive Assessment of Drought Risk for Summer Maize

Based on the above established drought risk evaluation index system for summer corn in Kaifeng City, the multi-level fuzzy comprehensive evaluation method is used to evaluate the drought level in Kaifeng City from 1992-2009, and the final evaluation score is calculated.

According to the above, multi-level fuzzy comprehensive evaluation is to conduct a first level fuzzy comprehensive evaluation starting from each underlying indicator set, and then use the obtained comprehensive evaluation as a first level indicator set as input data to conduct a second level fuzzy comprehensive evaluation, in order to obtain the summer corn drought risk evaluation results and their subordinate degrees in Kaifeng City.

3.6.1 Fuzzy Comprehensive Evaluation of Primary Indicators

Table 14. Annual Results Vector for Each Dimension

A particular year	Plant growth B1	Soil moisture B2	Disaster situation of corn B3
1992	[0.174,0.129,0.093,0.6]	[0.605,0.136,0.14,0.12]	[0.166,0.7,0.134,0]
1993	[0.353,0.565,0.082,0]	[0,0.23,0.77,0]	[0,0.045,0.29,0.665]
1994	[0.147,0.388,0.465,0]	[0.201,0.737,0.062,0]	[0.666,0.334,0,0]
1995	[0.936,0.064,0,0]	[0.554,0.446,0,0]	[1,0,0,0]
1996	[0.666,0.232,0.102,0]	[0.094,0.71,0.196,0]	[0,0,0,1]
1997	[0.312,0.252,0.436,0]	[0.882,0.006,0.112,0]	[0.166,0.789,0.045,0]
1998	[0.612,0.31,0.079,0]	[0.097,0.253,0,0.65]	[0.034,0.681,0.285,0]
1999	[0.509,0.3,0.19,0]	[0,0.361,0.289,0.35]	[0,0.045,0.29,0.665]
2000	[0.062,0.241,0.648,0.05]	[0,0,0,1]	[0.168,0.737,0.095,0]

Volume 9 Issue 5, 2023
DOI: 10.6919/ICJE.202305_9(5).0026

2001	[0.101,0.375,0.524,0]	[0.968,0.032,0,0]	[0.335,0.38,0.285,0]
2002	[0.446,0.554,0,0]	[0.295,0.055,0,0.65]	[0.101,0.804,0.095,0]
2003	[0,0.287,0.615,0.098]	[0,0.106,0.012,0.882]	[0,0.335,0.335,0.133]
2004	[0,0.076,0.32,0.604]	[0,0,0,1]	[0,0,0,1]
2005	[0,0.687,0.064,0.249]	[0,0.081,0.037,0.882]	[0,0.168,0.168,0.665]
2006	[0,0.093,0.205,0.702]	[0,0,0,1]	[0,0,0,1]
2007	[0.062,0.229,0.007,0.7]	[0,0,0,1]	[0,0,0,1]
2008	[0,0.65,0.252,0.098]	[0.576,0.306,0,0.118]	[0.168,0.737,0.095,0]
2009	[0.557,0.249,0.195,0]	[0.234,0.766,0,0]	[0.834,0.166,0,0]

3.6.2 Fuzzy Comprehensive Evaluation of Secondary Indicators

Table 15. Annual Two-level Fuzzy Relationship Matrix

A particular year	Two-level fuzzy relational matrix B
1993	[0.261,0.444,0.174,0.121]
1994	[0.246,0.406,0.349,0]
1995	[0.917,0.083,0,0]
1996	[0.5,0.228,0.091,0.182]
1997	[0.33,0.33,0.339,0]
1998	[0.466,0.373,0.11,0.051]
1999	[0.376,0.259,0.216,0.149]
2000	[0.076,0.312,0.496,0.115]
2001	[0.212,0.349,0.439,0]
2002	[0.371,0.56,0.017,0.051]
2003	[0,0.281,0.517,0.384]
2004	[0,0.056,0.237,0.707]
2005	[0,0.545,0.081,0.375]
2006	[0,0.069,0.151,0.78]
2007	[0.046,0.169,0.005,0.78]
2008	[0.076,0.639,0.203,0.082]
2009	[0.582,0.274,0.144,0]

3.6.3 Obtaining a Comprehensive Score based on the Weighted Average Principle

Based on the final weighted average principle, a comprehensive score of 1992-2009 was obtained. The drought situation in Kaifeng from 1992-2009 was obtained by comparing the drought severity table. From Table 15, it can be seen that the drought situation in 1992-2002 was relatively severe, especially between 1993-1999, with a comprehensive E value of over 50 for seven consecutive years, with the 1995 drought being the most severe. The drought situation in 2003-2007 has slowed down compared to previous years, and during these five years, it was basically around moderate drought. From the indicator data table, it can be seen that the yield of corn per mu in 2003-2007 was relatively high.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202305_9(5).0026

Table 16. Annual Comprehensive E-Value Table

A particular year	1992	1993	1994	1995
E	38.76	54.83	55.46	79.35
Drought degree	Centre	Centre	Centre	Weight
A particular year	1996	1997	1998	1999
E	58.99	57.43	64.40	54.46
Drought degree	Centre	Centre	Weight	Centre
A particular year	2000	2001	2002	2003
E	41.77	52.08	65.29	37.01
Drought degree	Centre	Centre	Weight	Centre
A particular year	2004	2005	2006	2007
E	17.83	39.47	16.69	22.01
Drought degree	Light	Centre	Light	Light
A particular year	2008	2009	-	-
E	52.25	68.32	-	-
Drought degree	Centre	Weight	-	-

4. Conclusion

Among the three selected indicator dimensions, the dimension with the greatest impact on drought risk assessment is the growth of summer corn, while the dimension with the smallest impact is the disaster situation of corn. Among the four primary indicators included in the growth of summer maize, the plant growth height can best reflect the growth of maize, while the grain weight has the weakest impact. By establishing a fuzzy comprehensive evaluation model, a drought risk assessment was conducted on summer corn in Kaifeng City from 1992-2009, and the drought severity from 1992-2009 was obtained as follows: medium, medium, medium, heavy, medium, medium, medium, heavy, medium, medium, heavy, medium, light, medium, light, light, medium, and heavy.

The drought in 1992-2002 was relatively severe, especially between 1993-1999, with a comprehensive E value of over 50 for seven consecutive years, with the 1995 drought being the most severe; The drought situation in 2003-2007 has slowed down compared to previous years, with a moderate drought in these five years; In the two years 2008-2009, there has been a rising trend of drought. According to statistics, from 1992 to 2009, there were 4 years of severe drought, 11 years of moderate drought, and 3 years of mild drought, with no significant drought.

References

[1] Cheng Yunping Agricultural Drought Risk Assessment and Zoning in Henan Province [D] North China University of Water Resources and Hydropower, 2016.

[2] Du Tiantian Risk Assessment of Agricultural Drought Disaster in Henan Province [D] North China University of Water Resources and Hydropower, 2017.

[3] Wang Dongfang, Zhang Fei, Zhou Mei, et al Research progress and development trend of agricultural drought risk [J] Anhui Agricultural Science, 2014,42 (17): 5455-5458

[4] Zhu Yeyu, Pan Pan, Kuang Xiaoyan, et al Analysis on the Changing Characteristics and Causes of Drought Disasters in Henan Province [J] China Agrometeorology, 2011,32 (02): 311-316.

[5] RAJKUMAR, DHAKAR, A M, et al. Probabilistic assessment of phenophase-wise agricultural drought risk under different sowing windows: a case study with rainfed soybean. [J]. Environmental monitoring and assessment, 2017.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202305_9(5).0026

[6] ISMAIL, DABANLI. Drought hazard, vulnerability, and risk assessment in Turkey[J]. Arabian Journal of Geosciences, 2018.

[7] DAVENPORT G. Simulating regional grain yield distributions to support agricultural drought risk assessment[J]. Applied Geography, 2015,63(Null).

[8] Zhang Jingjing, Guo Zhifu Agricultural Drought Risk Assessment in Henan Province Based on Projection Pursuit Model [J] Resources and Environment in Arid Areas, 2016,30 (06): 83-88.

[9] Zhou Pengfei Research on the Application of Fuzzy Comprehensive Evaluation Method in the Post Evaluation of Water Resources Demonstration of Construction Projects [D] Hebei Engineering University.

[10] Tan Xiaogang, Gao Guowei, Zhang Liqiang, etc. Design of agricultural soil humidity controller based on Arduino platform [J] Sensor World, 2016,22 (05): 30-34.

[11] National Climate Center, Department of Forecasting and Network, China Meteorological Administration, Lanzhou Institute of Drought Meteorology, China Meteorological Administration Meteorological drought level [S] General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China; China National Standardization Administration, 2017.

[12] Li Hui Comprehensive evaluation of reservoir resettlement risk in Tieling City based on fuzzy comprehensive evaluation method [J] Groundwater, 2019, 41 (01): 229-230.

[13] Zhao Qun Evaluation of production and living standards of reservoir migrants based on improved fuzzy comprehensive evaluation method [J] Water Conservancy Technical Supervision, 2018 (05): 120-125.

[14] Xie Shijun Risk analysis and evaluation of water conservancy projects based on multi-level fuzzy comprehensive risk evaluation model [J] Heilongjiang Water Conservancy Technology, 2018, 46 (11): 172-176.

[15] Drought disaster risk assessment method for maize [S] Domestic - Industry Standard - Industry Standard - Meteorological CN-QX.