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RESEARCH ARTICLE

# Intelligent Evaluation Model Based on Index System of Agricultural Industrial Chain

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**ABSTRACT** The whole agricultural industry chain is the breakthrough to develop the agricultural industry. In order to meet the needs of the optimized development of the agricultural industry, an intelligent evaluation model based on the index system of the whole agricultural industry chain is constructed. The kernel K-means clustering algorithm was used to mine the data of the whole agricultural industry chain from the big data platform of the whole agricultural industry chain. According to the clustering results, the index system of the whole agricultural industry chain was constructed, including five one-level indicators, including agricultural production index, technology extension index, information index, marketization index and risk guarantee index. The information entropy theory is used to calculate the weight of each index in the index system of the whole agricultural industry chain. According to the weight calculation results, the fuzzy comprehensive evaluation method is used to build an intelligent evaluation model, and the evaluation results of the development of the whole agricultural industry chain are output. Select agricultural area as the research object, the empirical analysis results show that the study area of agricultural industrial chain development evaluation result is 70 points, including customer service satisfaction, agricultural raw materials base size is weak in the whole industry chain development indicators, 2012-2019 study area of agricultural development of whole industry chain shows rising trend year by year.

**INDEX TERMS** Agricultural whole industrial chain, fuzzy comprehensive evaluation, index system, intelligent, evaluation model, information entropy theory.

## I. INTRODUCTION

Agriculture is an important industry that affects national economy, determines national income and national economic and social development [1]. Through perfecting the whole agricultural industry chain [2], building the strategic alliance of agricultural development [3], and enhancing the competitiveness of agricultural industry. The whole agricultural industry chain takes consumer demand as the follow-up production, sales and service target, and realizes the sales and transportation of agricultural products by collecting information of production bases, production enterprises and many other platforms. Use the information of the whole agricultural industry chain to guide the next round of production activities of the agricultural industry [4]. The whole agricultural industry chain has traceability [5], which promotes the development of agricultural industry in various countries [6] and guarantees the security of agricultural information [7], [8]. Modern agriculture has entered the scale and information development, combining emerging technologies such as Internet of Things and artificial intelligence with traditional agriculture. Using data clustering method to retain agricultural data has the characteristics of huge scale, various types and low value density, which extends and deepens the internal information flow of agriculture. Multi-spectral remote sensing information is acquired by airborne sensors, and the acquired agricultural information is transmitted to data nodes or terminals by using matching remote sensing data

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processing technology. Using the integration of production data and market data, we can effectively connect production and market information, balance the supply and demand of agricultural products in various places, and solve the problem of unbalanced distribution of agricultural resources. Transform the market demand data of agricultural products in various places into usable databases, optimize the production, processing, storage, transportation and sales of agricultural products, coordinate and control the flow of information, technology and other elements, and increase the value of agricultural products. The development level of the whole agricultural industry chain is of great significance to the development of national agricultural industry [9].

Deng et al. studied the performance evaluation and analysis method of cultivated land transfer in agricultural production industry [10], designed a comprehensive evaluation index system and evaluation criteria for cultivated land transfer in agricultural production industry, and comprehensively evaluated the cultivated land transfer in agricultural production industry through entropy weight method and fuzzy comprehensive evaluation method. The production space evaluation model of agricultural industry studied by Yan et al. deeply analyzed the production space distribution characteristics of agricultural industry, and based on the distribution characteristics, a comprehensive evaluation of the function of the production space system of agricultural industry was achieved, providing reliable theoretical guidance for the development of the whole agricultural industrial chain [11]. Severini et al. constructed a risk management model for the whole agricultural industry, which evaluated the stable income of people in the whole agricultural industry through income stabilization tools, and provided a theoretical basis for the development of the agricultural industry. These research methods can only achieve the local function evaluation of the whole agricultural industry chain, but cannot achieve the overall function evaluation of the whole agricultural industry chain, which has certain limitations [12].

Aiming at the shortcomings in the above research, an intelligent evaluation model based on the agricultural whole industry chain index system is constructed. The relevant data of the agricultural whole industry chain is collected by using the big data platform of the agricultural whole industry chain. The kernel K-means clustering algorithm is used to mine the data of the agricultural whole industry chain, and the agricultural whole industry chain index system is constructed. Using the index system of agricultural whole industry chain constructed, the intelligent evaluation of agricultural whole industry chain is realized by fuzzy comprehensive evaluation method.

## II. AGRICULTURAL WHOLE INDUSTRIAL CHAIN THEORY FOUNDATION AND INDEX SYSTEM CONSTRUCTION

### A. AGRICULTURAL WHOLE INDUSTRY CHAIN COMPOSITION STRUCTURE AND FUNCTION

Industrial chain is an important concept in economics. Industrial chain refers to the relationship between inputs and outputs of upstream and downstream industries formed by differential division of labor between industries. The development of industrial chain is closely related to knowledge and technological level, which deepens the organizational form of industrial chain. The whole agricultural industry chain refers to the association relationship of all links related to the agricultural industry. The composition structure of the whole agricultural industry chain is shown in Fig. 1.

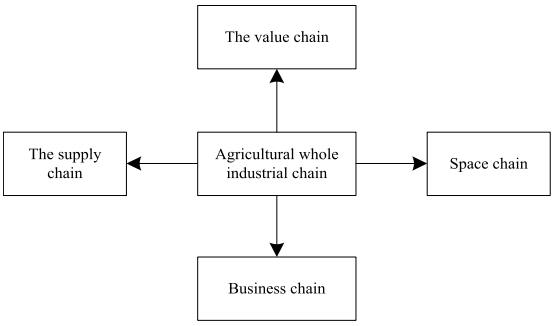


**FIGURE 1.** Structure of the whole agricultural industry chain.

As can be seen from Fig. 1, the whole agricultural industry chain is a combination of four dimensions, namely spatial chain, value chain, enterprise chain and supply and demand chain. The value chain refers to the dynamic process of creating value in the process of designing, producing, selling, sending and assisting agricultural products production, which can coordinate the whole process of agricultural production in time and enhance value activities and marginal profits. The supply chain refers to a process with a life cycle, which can integrate materials, information, capital and knowledge flow to meet the needs of end users. Spatial chain refers to the distribution of the same industrial chain in different regions, which can deepen the cross relationship between agricultural industrial chains. Business chain refers to the enterprise chain formed by the flow and interaction of enterprise life bodies through materials, capital, technology, etc. With the help of regional market, it coordinates the contradiction between specialized division of labor and multi-dimensional demand among regions, and realizes the carrier of regional cooperation in form and content. The chains of different dimensions are interrelated and constitute the results of the whole agricultural industry chain. The formation of the whole agricultural industry chain can enhance the value of agricultural industry and realize the appreciation of agricultural industry. Improving the development of the whole agricultural industry chain [13] is an important way to reduce the cost of agricultural production enterprises and agricultural sales enterprises and promote the development of agricultural industry. Through the joint action of the four dimensions of the agricultural industry chain, the profit appreciation of the agricultural industry can be realized.

The whole agricultural industry chain not only has the functional characteristics of agricultural industry, but also has unique functions. The whole agricultural industry chain has

many functions, such as resource integration and industry strengthening. Many links in the whole agricultural industry chain interact and depend on each other to realize the value-added of agricultural industry. The whole agricultural industry chain mainly includes the following functions:

(1) Industrial strengthening function

When many things in the agricultural industry are organically combined, synergistic effect can be produced. Many parts of the agricultural industry chain act together to give full play to the synergistic effect of things and strengthen the development of agricultural industry. The whole agricultural industrial chain combines agricultural production, agricultural processing and agricultural sales departments, and many departments combine to form agglomeration effect and enhance the development scale of agricultural economy. To construct the whole agricultural industry chain, expand the agglomeration effect of the industry chain, and elongate the agricultural industry chain. Through the association of upstream and downstream enterprises, the relevant industries of the agricultural industry will be horizontally expanded to meet the functions of R&D, production, marketing and complementary functions of the agricultural industry. When processing agricultural products [14], agricultural production enterprises share facilities and technologies of the whole industrial chain to improve production efficiency. The whole agricultural industry chain uses specialized division of labor technology to coordinate all links of agricultural products before, during and after production, improve the management efficiency of different links of the whole industrial chain, and provide a good foundation for the sale of agricultural products. Through the cooperation of many departments of the whole industry chain, avoid the waste of resources and enhance the competitiveness of the whole industry chain.

(2) Resource integration function

The whole agricultural industry chain can realize the integration of agricultural resources, balance all links of the whole agricultural industry chain, and obtain the best agricultural industry performance. Use the agricultural industrial chain to improve the interests of the agricultural industry, average industrial profits, and achieve a good optimization of the allocation of resources in the agricultural market mechanism. Many participants in the whole agricultural industry chain need to cooperate and coordinate with each other in order to pursue the maximization of their own interests. Through the mutual restriction between upstream enterprises and downstream enterprises, agricultural production enterprises can obtain stable raw materials [15], provide consumers with a larger service market, reduce the signing cost of agricultural production, and improve the competitiveness of agricultural production enterprises and sales enterprises.

(3) Value enhancement function

All agricultural industry chain through the different links of cooperation, improve the added value of agricultural products, through to the agricultural investment, agricultural production technology [16], jobs for the residents to agricultural production area, give full play to the agriculture, relationships between all the whole industry chain link function, create greater value for society and the country, with the improvement of the whole industrial chain of agriculture, Increase social wealth. When the whole agricultural industry chain is relatively perfect, with the deepening of agricultural product processing, the external characteristics of agricultural industry will be changed and the functions of agricultural products will be improved. The efficiency of the use of agricultural products and resources will increase, creating more value for the agricultural industry. Through the processing of agricultural products, the whole agricultural industry chain connects many participants in the whole agricultural industry chain and expands the agricultural market.

### B. THE DEVELOPMENT MODE OF AGRICULTURAL WHOLE INDUSTRIAL CHAIN

Information technology is an important part of the whole agricultural industry chain. The whole agricultural industry chain combines the Internet of things, scientific and technological services and other information service levels, and the information service in the whole agricultural industry chain needs to run through all the links before, during and after the production of agricultural products. In the process of processing, logistics and sales of agricultural products, information technology needs to participate in the whole process. Consumers make use of the information construction of the whole agricultural industry chain to inquire the specific information of each link, so that agricultural product information has higher transparency and avoid safety problems of agricultural products. The information management technology is integrated into the whole agricultural industry chain, and the information development mode of the whole agricultural industry chain is obtained, as shown in Fig. 2.

As can be seen from the information mode of the whole agricultural industry chain in Fig. 2, the whole agricultural industry chain combines many technologies such as agricultural Internet of things technology, e-commerce sales of agricultural products, remote scientific and technological services, and realizes the information development of the whole agricultural industry chain through many information technologies. In the process of agricultural processing and production, a large number of sensor nodes are used to form a monitoring network, and various sensors are used to collect information, so as to help farmers find problems in time and accurately determine the location of problems. The agricultural production mode is turned to information and software as the center, thus increasing the frequency of use of automatic, intelligent and remotely controlled production equipment. Remote technical service can provide farmers with real-time technical questions and advice, and experts and farmers can communicate face to face through the network to realize remote diagnosis of diseases and insect pests, remote monitoring of diseases and remote working meetings. As a substitute signal of collateral, agricultural insurance can effectively alleviate the restriction of credit rationing for farmers, increase their credit availability and credit limit, and

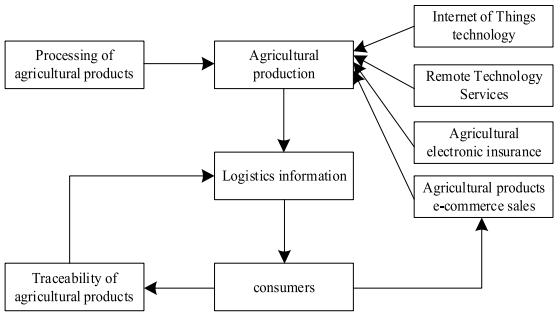


**FIGURE 2.** Information mode of the whole agricultural industry chain.

improve the income level of farmers. E-commerce sales of agricultural products is the comprehensive introduction of e-commerce system in the production and sales management of agricultural products. Information technology is used to publish and collect information such as supply and demand, price, etc. With the network as the medium and relying on the agricultural production base and logistics distribution system, agricultural products trading and monetary payment can be realized quickly and safely.

The whole agricultural industry chain can be developed through multiple models. The main development models of the whole agricultural industry chain are as follows:

(1) Hybrid, vertical and integrated cooperation mode

The hybrid, vertical and integrated cooperation mode of the whole agricultural industry chain is dominated by agricultural enterprises, which use marketing markets and agricultural production bases to provide required content for the development of the whole agricultural industry chain. Under this cooperation mode, the whole agricultural industry chain needs to be combined with many organizations such as logistics distribution and farmers [17] to horizontally adjust the behaviors of agricultural enterprises, farmers and logistics enterprises, and optimize the whole agricultural industry chain through dynamic adjustment.

(2) Cooperation mode of market + enterprise + farmer

Under the cooperation mode of the whole agricultural industry chain, relying on agricultural specialized markets and agricultural production bases, the agricultural products produced by surrounding farmers are used to provide assistance for the whole agricultural industry chain. The cooperation mode of the whole agricultural industry chain under this mode promotes the development of agricultural industries around agricultural enterprises and agricultural production bases.

(3) Brand + standard + scale agricultural whole industrial chain model

This model is the highest development form of the agricultural whole industry chain model. The agricultural whole industry chain model under this model, through continuous development, forms a brand, and uses the role of brand effect to promote the further development of the whole agricultural industry chain. Under this model, the agricultural whole industry chain mode keeps developing. Through high standards and large-scale construction of agricultural brand, the highest development form of the agricultural whole industry chain mode is completed.

### C. COLLECTION AND INTEGRATION OF DATA RESOURCES OF THE WHOLE AGRICULTURAL INDUSTRY CHAIN

The whole agricultural industry chain needs to connect the production and sales of agricultural products and promote the development of agriculture through the whole industry chain. Building a big data platform for the whole agricultural industry chain is an important way to realize the integration of massive resources in the whole agricultural industry chain. In the process of agricultural industry development, a large amount of data has been accumulated, including the variety data and breeding data of agricultural products before production, processing data and economic data in the production process, and logistics data in the sales process. Massive agricultural data is the basis for promoting the development of China's agricultural industry. Since the data of the whole agricultural industry chain is too scattered, a platform that can integrate the data of the whole agricultural industry chain should be built, which contains the data resources of the whole process of production and sales of agricultural products [18] to support the mining and application of agricultural big data. The forms of agricultural industry data are diverse, the types of data resources are numerous, the data sources are extremely wide, and the amount of data growth is extremely high. The big data form and data dispersion of agricultural data lead to a low development and utilization rate of agricultural data, and massive agricultural industry data cannot be efficiently applied, which affects the development process of the whole agricultural industry chain.

To build a big data analysis platform applied in the intelligent evaluation of the whole agricultural industry chain, provide a good foundation for the data mining of the whole agricultural industry chain, meet the needs of the optimization of the layout of the whole agricultural industry chain in China, and meet the needs of scientific and technological innovation, production and processing, as well as the market and consumers in the process of agricultural industry development. The big data platform architecture for data analysis of the whole agricultural industry chain is shown in Fig. 3.

As can be seen from Fig. 3, the big data platform of the whole agricultural industry chain consists of infrastructure layer, agricultural resource center, knowledge center and application layer.

The infrastructure layer includes computing facilities, network hardware, and memory in the big data platform of the whole agricultural industry chain. The infrastructure layer is used to provide facility support for the big data platform of the whole agricultural industry chain.

Agricultural resource center including agricultural production data, data, cost and benefit of agricultural machinery, agricultural logistics data, agricultural policies and regulations, as well as agricultural electricity data and so on the whole industrial chain related data, the use of agricultural

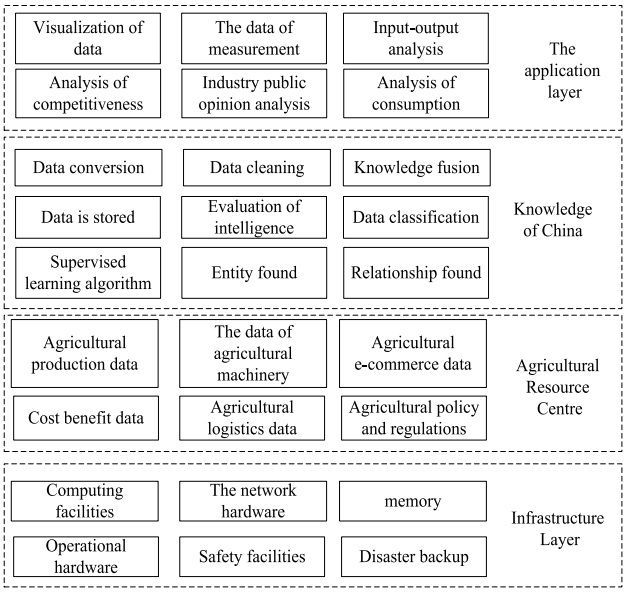


**FIGURE 3.** Big Data platform architecture of the whole agricultural industry chain.

resources center [19], as whole industrial chain of agriculture intelligent evaluation of sources of data, provide data support for agriculture industry chain all intelligent evaluation.

The knowledge center includes data conversion, data cleaning, knowledge fusion and many other technologies to realize the collection, storage and management of the whole agricultural industry chain data. The intelligent operation method contained in the knowledge platform is used to obtain the correlation relationship between numerous data before, during and after production of the whole agricultural industry chain, complete the good integration of massive multi-source heterogeneous data, and the integration of intelligent evaluation data resources of the whole agricultural industry chain.

Using the functional modules of data visualization, competitiveness analysis, input-output analysis and so on, the application layer provides data audit, data push, service monitoring and other functions for the whole industrial chain data to support the application of the whole agricultural industrial chain. The whole process of data processing of the whole agricultural industry chain is displayed to users with the data visualization function. Based on the data of the whole agricultural industry chain and the intelligent evaluation results of the whole agricultural industry chain, the managers of the whole agricultural industry chain complete many functions such as the analysis of the public opinion of the agricultural industry and the analysis of the competitiveness of the agricultural industry. The service of the big Data platform of the whole agricultural industry chain is for agricultural production personnel, agricultural operators, government, consumers and many other subjects. Users can use mobile phones, computers and other terminals to access the big data platform of the whole agricultural industry chain in real time, and realize the real-time application of the big data of the whole agricultural industry chain.

### D. KERNEL K-MEANS CLUSTERING ALGORITHM FOR AGRICULTURAL WHOLE INDUSTRIAL CHAIN DATA CLUSTERING

The kernel K-means clustering algorithm is used to mine the whole agricultural industry chain data from the big data platform of the whole agricultural industry chain, and the clustering results are used to construct the index system of the whole agricultural industry chain. Kernel K-means clustering algorithm is to map the agricultural whole industry chain data sample $x$ in the original space $R^n$ of the agricultural whole industry chain big data platform to the high-dimensional feature kernel space by using the nonlinear mapping function $\phi{:}R^n \rightarrow F, x \rightarrow \phi(x)$, and perform K-means clustering on the agricultural whole industry chain data sample in the high-dimensional kernel space. The data sample $x_i$ of the whole agricultural industry chain is converted into $(\phi(x_1), \cdots, \phi(x_n))$ in the high-dimensional feature kernel space, and the objective function of kernel K-means clustering for the data sample of the whole agricultural industry chain is as follows:

$$\min \phi = \sum_{i=1}^{N} \left\| \phi(x_i) - m_i^{\phi} \right\|^2 \tag{1}$$

In Equation (1), $m_i^{\phi}$ represents the sample mean. $N$ represents the total number of samples. $m_i^{\phi}$ is calculated using the following formula:

$$m_i^{\phi} = \sum_{i=1}^{N} \phi(x_i)/N_k \tag{2}$$

In Equation (2), $N_k$ represents the center point corresponding to the cluster.

In the high-dimensional kernel space of kernel K-means clustering algorithm, the distance formula between random agricultural whole industry chain data sample $\phi(x_i)$ and the mean value $m_i^{\phi}$ of an agricultural whole industry chain category is as follows:

$$\begin{aligned} \|\phi(x)\| - m_i^{\phi} &= \left| \phi(x) - \sum_{i=1}^{N} \phi(x_i) \right|^2 \\ &= k(x,x) - 2\sum_{i=1}^{N_k} k(x,x_i) + \sum_{i,j=1}^{N_k} k(x_i,x_j) \end{aligned} \tag{3}$$

In Equation (3), $k(x, y)$ represents the kernel function. The Gaussian kernel function is selected as the kernel function of the kernel K-means clustering algorithm. The calculation formula of the Gaussian kernel function is as follows:

$$k(x,y) = \exp\left[ -\|x-y\|^2 / 2\sigma^2 \right] \tag{4}$$

In Equation (4), $\sigma$ represents the kernel parameter.

The kernel K-means clustering algorithm is used to cluster the whole agricultural industry chain data as follows:

Input: Set the number of categories of agricultural whole industrial chain data to be clustered as the number $m$ of

clusters to be divided, and determine the kernel function $k(x, y)$ and the distance parameter of clustering.

(1) The sample $x_i$ in the agricultural whole industry chain data set $X$ is mapped from the original space to the high-dimensional kernel space using kernel function $k(x, y)$, and $X'$ is used to represent the agricultural whole industry chain data set in the high-dimensional space after mapping, and the sample $X'$ in the high-dimensional space is represented by $x_i'$.

(2) From the whole agricultural industry chain data set, a number of $k$ samples are randomly selected as the initial cluster center set $C = \left(m_1^{\phi}, \cdots, m_k^{\phi}\right)$ of the kernel k-means clustering algorithm.

(3) According to the kernel distance formula of equation (3), $x_i'$ is divided into the cluster core center $m_i^{\phi}$ nearest to the data sample.

(4) Recalculate the updated cluster center $\left(m_1^{\phi}, \cdots, m_k^{\phi}\right)$.

According to the classification results of the whole agricultural industry chain output in step (3), different samples of the whole agricultural industry chain are selected as clustering centers. Calculate the sum of distances between the selected cluster centers and other sample points in different categories. The class with the minimum sum of distances is the class center of the clustering result of the whole agricultural industrial chain.

(5) Repeat steps (3) and (4) until the maximum number of iterations is met or the objective function does not change.

Output: Clusters that meet the objective function of data clustering of the whole agricultural industry chain.

### E. AGRICULTURAL WHOLE INDUSTRIAL CHAIN INDEX SYSTEM CONSTRUCTION

The whole agricultural industry chain involves many links, and there is obvious correlation between each link. Agricultural production index can reflect the objective economic relationship between various production resources and labor achievements in agricultural production. Technical promotion index can fully reflect the characteristics of agricultural production, comprehensively and accurately reflect the complex contents and influencing factors of agricultural technical and economic effects. Index of informatization can measure and reflect the expected effect of agricultural production schemes. Indicators of marketization can reflect the quantitative relationship between current agricultural effect and long-term effect, local effect and overall effect. Risk protection index can reflect the causal and functional relationship between input and output in agricultural production. Therefore, these five indicators are selected to construct the index system of the whole agricultural industry chain.

When constructing the index system of the whole agricultural industry chain, it is necessary to consider the influence degree of many indexes on the intelligent evaluation of the index system of the whole agricultural industry chain. According to the clustering results of the kernel K-means clustering algorithm on the whole agricultural industry chain data, the index system of the whole agricultural industry chain is constructed as shown in Table 1.

The index system of the whole agricultural industry chain constructed includes five first-level indicators, including agricultural production index, technology extension index, information index, marketization index and risk guarantee index, and each first-level indicator contains a number of second-level indicators. The index system of the whole agricultural industry chain constructed covers the whole process of agricultural production before, during and after production, including all links of the operation of the whole agricultural industry chain, and takes into account the risks in the operation of the whole agricultural industry chain [20]. The index system of the whole agricultural industry chain constructed was used as the index basis for the intelligent evaluation of the whole agricultural industry chain, and the intelligent evaluation results of the whole agricultural industry chain were obtained.

## III. INTELLIGENT EVALUATION MODEL OF AGRICULTURAL WHOLE INDUSTRIAL CHAIN INDEX SYSTEM

### A. AGRICULTURAL WHOLE INDUSTRIAL CHAIN INDEX WEIGHT CALCULATION

The information entropy theory is used to calculate the weight of each index in the index system of the whole agricultural industrial chain. $U_i$ and $U_{ij}$ are respectively used to represent the first-level indicators and second-level indicators in the index set of the whole agricultural industry chain index system in Table 1. The number of first-level indicators and second-level indicators are respectively represented by $n$ and $m$. The index weight of agricultural whole industrial chain index system is calculated by information entropy theory. In order to avoid the subjectivity affecting the evaluation results when calculating the index weights of the whole agricultural industry chain, the subjective weighting method and objective weighting method were combined, and the information entropy theory was used to modify the weight results obtained by the subjective weighting method, so as to make the index weights obtained by the agricultural whole industry chain index system more accurate.

The calculation process of index weight in the index system of the whole agricultural industry chain is as follows:

(1) Construct the intelligent evaluation index matrix of the whole agricultural industrial chain

In the problem domain of intelligent evaluation of agricultural whole industrial chain index system, the second-level index value $j$ under first-level index $i$ in agricultural whole industrial chain index system is denoted by $x_{ij}$. The expression of the intelligent evaluation matrix of the first-level index in the agricultural whole industrial chain index system is as follows:

$$S_i = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \tag{5}$$

**TABLE 1.** Agricultural whole industrial chain index system.

| The total index layer | Level indicators | The secondary indicators |
|---|---|---|
| Intelligent evaluation of the whole agricultural industrial chain | Agricultural production index | Ratio of skilled personnel |
| | | High and new technology introduction rate |
| | | Standard coverage rate of agricultural products |
| | | Product compliance rate |
| | | Average agricultural output value |
| | | Vegetation coverage rate |
| | | Agricultural raw material base scale |
| | | Increase rate of added value of agricultural products |
| | | Diversity of products |
| | Technical promotion index | Ability to popularize agricultural technology |
| | | Level of agricultural technical popularization |
| | | Efficiency of agro-technical extension |
| | Index of informatization | Agricultural industrial chain information processing level |
| | | Level of logistics informatization |
| | | Agricultural industrial chain information dissemination level |
| | | Agricultural industrial chain information utilization level |
| | Indicators of marketization | Production capacity of agricultural products |
| | | Agricultural industry chain market potential |
| | | Agricultural industry chain market ability |
| | | Customer service satisfaction |
| | | Net return per unit area |
| | | Employee income growth rate |
| | | Peripheral employment rate increase |
| | Risk protection index | Degree of perfection of laws and regulations |
| | | The degree of government policy improvement |
| | | Risk protection level |

(2) Normalize the absolute index value in the index system of the whole agricultural industry chain

In the index system of the whole agricultural industry chain, the range and unit of different index values are quite different. There are positive indicators and negative indicators in the index system of the whole agricultural industry chain. Positive and negative indicators are used to distinguish the positive indicators and negative indicators in the index system of the whole agricultural industry chain. The index system of the agricultural whole industry chain is normalized, and the expression of index $x_{ij}$ of the agricultural whole industry chain is transformed from absolute value to relative value as follows:

$$x'_{ij} = \left( \frac{x_{ij} - \min\left(x_{i1}, x_{i2}, \cdots, x_{im}\right)}{\max(x_{i1}, x_{i2}, \cdots, x_{im}) - \min(x_{i1}, x_{i2}, \cdots, x_{im})} \right) \times 100 \tag{6}$$

The index value of the whole agricultural industry chain after normalization is used for the intelligent evaluation of the whole agricultural industry chain.

(3) Calculate the relative value of index $x_{ij}$ in the index system of the whole agricultural industry chain and the proportion of index X in the intelligent evaluation sample. The calculation expression of the relative value proportion of index $x_{ij}$ is as follows:

$$p_{ij} = x_{ij} / \sum_{j=1}^{m} x_{ij} \tag{7}$$

(4) Entropy value can reflect the amount of information reflected by different indicators in the intelligent evaluation process of the whole agricultural industry chain. The formula for calculating the entropy value of index $x_{ij}$ is as follows:

$$e_{ij} = -\sum_{j=1}^{m} p_{ij} \ln\left(p_{ij}\right) / \ln r \tag{8}$$

In the above equation, $1/\ln r$ represents coefficient location, and $1/\ln r$ is used to ensure $0 \leq e_{ij} \leq 1$.

(5) Calculate the difference coefficient of each index in the index system of the whole agricultural industrial chain.

Index system in the whole industry chain, in a fixed index, other indicators and the index has a higher degree of discrete, said the index's importance in the whole industry chain in agriculture intelligent evaluation is higher, while the index has the smaller the entropy value, with smaller entropy gives higher weights are all the agricultural industrial chain. In the index system of the whole agricultural industry chain, the difference coefficient expression of the second-level index $x_{ij}$ is as follows:

$$d_{ij} = 1 - e_{ij} \tag{9}$$

When the calculation result $d_{ij}$ of the difference coefficient of the second-level index $x_{ij}$ of the whole agricultural industry chain is 0, it means that this index has no influence on the intelligent evaluation result of the whole agricultural industry chain. This index can be deleted and its weight set to 0.

(6) Based on the calculation results of the difference coefficient of indicators of the whole agricultural industry chain, the weight calculation formula of the second-level index $x_{ij}$ in the index system of the whole agricultural industry chain is as follows:

$$w_{ij} = d_{ij} / \sum_{j=1}^{m} d_{ij} = \left(1 - e_{ij}\right) / m - \sum_{j=1}^{m} e_{ij} \tag{10}$$

Equation (10) should satisfy $0 \leq w_{ij} \leq 1$, $\sum_{j=1}^{m} w_{ij} = 1$. The above process is used to obtain all the index weights in the agricultural whole industrial chain index system.

### B. INTELLIGENT EVALUATION MODEL OF WHOLE AGRICULTURAL INDUSTRY CHAIN BASED ON FUZZY COMPREHENSIVE EVALUATION METHOD

Fuzzy comprehensive evaluation method is an important method in fuzzy decision-making method. Membership function is used to embody the fuzzy concept in the intelligent evaluation of the whole agricultural industrial chain and realize the effective quantification of fuzzy characteristics of things. The fuzzy comprehensive evaluation method quantifies the factors that are not clear boundaries and cannot be easily quantified. According to the fuzzy rule parameters of fuzzy evaluation alternatives, the comprehensive evaluation results are ranked to obtain the optimal scheme in the application of intelligent evaluation of the whole agricultural industry chain.

According to the index system of the whole agricultural industry chain, the process of constructing the intelligent evaluation model of the whole agricultural industry chain by using the fuzzy comprehensive evaluation method is as follows:

(1) According to the index system of the whole agricultural industry chain in Table 1, the index system of the whole agricultural industry chain contains 5 first-level indicators, which are respectively $U_1, U_2 \ldots, U_5$ is used to construct a finite set $U = \{U_1, U_2, \cdots, U_5\}$ with first-level indicators.

(2) According to the intelligent evaluation needs of the whole agricultural industry chain, the intelligent evaluation results of the whole agricultural industry chain can be divided into 5 levels, which are denoted by $V_1$, $V_2$ $\ldots$ $V_5$. The whole agricultural industry chain with limited composition is represented by $V = \{V_1, V_2, \cdots, V_5\}$. The grade system is selected as the grade division method of the intelligent evaluation of the whole agricultural industry chain. The grade division results of the intelligent evaluation of the whole agricultural industry chain are shown in Table 2.

(3) In order to make the intelligent evaluation result of the whole agricultural industry chain more objective, the evaluation matrix of the index system of the whole agricultural industry chain is constructed by using the expert scoring method. Expert scoring method is a qualitative description and quantitative method. Select a number of evaluation items according to the specific requirements of evaluation objects, formulate evaluation criteria according to the evaluation items, hire a number of representative experts to give the evaluation scores of each item according to the evaluation criteria based on their own experience, and then collect them. The expert scoring method is simple and intuitive in determining the appropriate evaluation items according to the specific evaluation objects in agricultural information collation. When summarizing agricultural information, the calculation method is simple, and there is a large choice. When agricultural forecast is completed, both quantitative evaluation items and those that cannot be calculated can be calculated. Experts determine a grade $V_i$ from the evaluation set $V$ for the first-level index $U_i$ in the index system of the whole agricultural industry chain. When the number of experts is $L$, and the number of people in the index system of the whole agricultural industry chain whose index $U_i$ belongs to grade $V_i$ is $L$, the fuzzy set of expert evaluation on factor $U_i$ can be determined. Through the above process, the evaluation opinions of experts on the indicators of the whole agricultural industry chain are sorted out and the final evaluation matrix is obtained.

(4) The fuzzy data method is used to carry out fuzzy operation on the constructed evaluation matrix to obtain the quantitative evaluation result $R_{ij}$ of each secondary index of the whole agricultural industry chain.

(5) Determine the weight of indicators

The information entropy method studied in Section 3.1 is used to determine the weight $w_i$ of each first-level index and the weight $w_{ij}$ of the second-level index in the index system of the whole agricultural industry chain.

(6) Second-level fuzzy evaluation

Using the quantitative evaluation result $R_{ij}$ of the second-level index and the weight $w_{ij}$ of the second-level index, the expression of the second-level fuzzy evaluation is obtained as follows:

$$R_i = \sum_{j=1}^{m} w_{ij} R_{ij} \tag{11}$$

(7) Comprehensive evaluation results

Using the second-level fuzzy evaluation results, the expression of intelligent evaluation model of agricultural whole industrial chain index system is obtained as follows:

$$R = \sum_{i=1}^{n} w_i R_i \tag{12}$$

The intelligent evaluation model of agricultural whole industrial chain index system based on formula (12) is used to evaluate the overall level of agricultural whole industrial chain. After determining the final comprehensive evaluation result, it is necessary to explain and explain the evaluation index. The fuzzy distribution principle and the maximum membership principle should be satisfied when the intelligent evaluation results of the whole agricultural industrial chain are interpreted. The intelligent evaluation results of the whole agricultural industry chain can be used to provide objective

**TABLE 2. Division of intelligent evaluation results of the whole agricultural industrial chain.**

| score | Level division | level | Level description |
|---|---|---|---|
| 0-20 | 5 | very poor | The development degree of the whole agricultural industrial chain is very poor, and the economic and social ecological benefits are very poor |
| 20-40 | 4 | poor | The development degree of the whole agricultural industrial chain is poor, and the economic and social ecological benefits are poor |
| 40-60 | 3 | general | The development degree of the whole agricultural industrial chain is average, and the economic and social ecological benefits are average |
| 60-80 | 2 | good | The whole agricultural industry chain is well developed, with good economic and social ecological benefits |
| 80-100 | 1 | very good | The development of the whole agricultural industrial chain is excellent, and its economic and social ecological benefits are excellent |

basis for competent departments at all levels to formulate relevant strategies for the management of the whole agricultural industry chain. The fuzzy comprehensive evaluation method can realize the comprehensive evaluation by quantifying the factors that have fuzzy boundary and cannot be easily quantified. Fuzzy comprehensive evaluation method is suitable for the application with many evaluation factors and high fuzziness, and has high operability and scientificity. When the agricultural industry makes corresponding policies, it is necessary to closely connect with the relevant links of the whole agricultural industry chain and clarify the existing situation of the whole agricultural industry chain. Using constructed index system of whole industry chain of agriculture, for the whole industry chain functional effect agriculture intelligent evaluation, to obtain the objective of intelligent evaluation standard, make agricultural state of management of the whole industry chain for agriculture to objective and standard of judgment results, reflect the performance of the whole industry chain, clear agricultural problems that exist in the whole industry chain operation. The intelligent evaluation results of the whole agricultural industry chain can determine the specific management measures for the decision makers of the whole agricultural industry chain, and optimize the control of the whole agricultural industry chain by adjusting the quantity of manpower, material and financial resources.

## IV. EMPIRICAL ANALYSIS RESULTS AND DISCUSSION

According to the constructed index system of the whole agricultural industry chain, an agricultural region in a city was selected as the research object of the intelligent evaluation of the whole agricultural industry chain. The relevant data of the whole agricultural industry chain in the study area from 2012 to 2019 were collected and sorted out, and the development of the whole agricultural industry chain in the study area was evaluated by using the constructed intelligent evaluation results. The study area is located in the southeast coastal area of China and contains a large river. The total land area of the study area is 206,400 square kilometers, with 72.85% of mountains and hills, 21.52% of plains and basins, and 5.63% of rivers and lakes. The study area has a diverse climate and rich agricultural resources. In recent years, different types of agriculture such as forestry, animal husbandry and fishery have been comprehensively developed. Agricultural products include vegetables, tea, flowers and fruits. Regional managers pay attention to agricultural development, and agricultural market-oriented reform is an important way to promote the sustainable development of agricultural market. In recent years, the agricultural and rural economy in the study area has developed rapidly. The income of rural residents in the study area has been at the top of the provincial level for many years.

The development of agricultural industry in the study area is very characteristic, and the output value of leading agricultural industry accounts for a high proportion. The study area uses the flexible agricultural management mechanism to promote the development of agricultural industry. Agricultural industry has a higher level of industrialization management.

The intelligent evaluation model constructed in this paper is used to calculate the weight results of the agricultural whole industrial chain index system, as shown in Table 3.

According to Table 3, the agricultural production index, technology extension index, Index of informatization, Indicators of marketization and risk protection index have low weights and have a good development trend. It is proved that the proposed method can effectively obtain the development of the whole agricultural industrial chain, help solve the problems that the current agricultural industrial chain is generally short and the value chain is generally low, help to increase the agricultural gross production value, and provide a strategic fulcrum for the double circulation pattern. According to the weight calculation results of the agricultural whole industrial chain index system in Table 3, the development of the agricultural whole industrial chain in the study area is intelligently evaluated. The intelligent evaluation results of the second-level indicators of the whole agricultural industry chain in the study area in 2019 were statistically analyzed. The statistical results are shown in Table 4.

According to Table 4, it can be seen that each secondary index of the whole agricultural industry chain is in a high score, and only customer service satisfaction is in a low score. It is proved that the proposed method can effectively obtain all the information in value chain, supply chain, space chain and business chain, and provide technical support for the subsequent optimization and upgrading of inferior content. According to the calculation results of the second-level indicators of the whole agricultural industry chain in 2019, the

**TABLE 3.** Weight of agricultural whole industrial chain index system.

| Level indicators | The weight | The secondary indicators | The weight |
|---|---|---|---|
| Agricultural production index | 0.25 | Ratio of skilled personnel | 0.15 |
| | | High and new technology introduction rate | 0.05 |
| | | Standard coverage rate of agricultural products | 0.08 |
| | | Product compliance rate | 0.15 |
| | | Average agricultural output value | 0.14 |
| | | Vegetation coverage rate | 0.12 |
| | | Agricultural raw material base scale | 0.14 |
| | | Increase rate of added value of agricultural products | 0.09 |
| | | Diversity of products | 0.08 |
| Technical promotion index | 0.17 | Ability to popularize agricultural technology | 0.35 |
| | | Level of agricultural technical popularization | 0.34 |
| | | Efficiency of agro-technical extension | 0.31 |
| Index of informatization | 0.21 | Agricultural industrial chain information processing level | 0.19 |
| | | Level of logistics informatization | 0.29 |
| | | Agricultural industrial chain information dissemination level | 0.31 |
| | | Agricultural industrial chain information utilization level | 0.21 |
| Indicators of marketization | 0.13 | Production capacity of agricultural products | 0.18 |
| | | Agricultural industry chain market potential | 0.12 |
| | | Agricultural industry chain market ability | 0.16 |
| | | Customer service satisfaction | 0.14 |
| | | Net return per unit area | 0.16 |
| | | Employee income growth rate | 0.15 |
| | | Peripheral employment rate increase | 0.09 |
| Risk protection index | 0.24 | Degree of perfection of laws and regulations | 0.34 |
| | | The degree of government policy improvement | 0.32 |
| | | Risk protection level | 0.34 |

results of each first-level indicator of the whole agricultural industry chain are shown in Fig. 4.

According to Fig. 4, the agricultural production index scores 65 points, the technical popularization index scores 73.7 points, the Index of informatization scores 74 points, the Indicators of marketization scores 58.6 points and the risk protection index scores 72.7 points. According to the constructed index system of the whole agricultural industry chain, the first-level index evaluation results of the whole agricultural industry chain in the study area in 2019 can be effectively obtained. Through the research, the final score of regional agricultural industrial chain development in 2019 is 68.8 points. Substituting the intelligent evaluation scores of the whole agricultural industry chain into Table 2, it can be seen that the intelligent evaluation results of the development of the whole agricultural industry chain in the study region are good. Among them, customer service satisfaction and the scale of agricultural raw material base are relatively weak indicators for the development of the whole agricultural industry chain in the study region. Corresponding policies should be formulated based on the above two indicators to improve the development level of the whole agricultural industry chain in the study region.

In order to further verify the effect of the studied intelligent evaluation model on the intelligent evaluation of the whole agricultural industry chain in the study region and clarify the development status of the whole agricultural industry chain in the study region, the intelligent evaluation results of the whole agricultural industry chain in the study region from 2012 to 2019 were statistically analyzed. The statistical results are shown in Fig. 5.

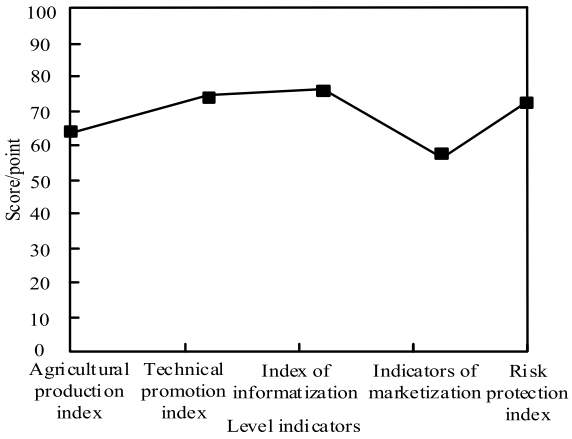


**FIGURE 4.** Intelligent evaluation results of first-level indicators of the whole agricultural industry chain.

As can be seen from the intelligent evaluation results of the whole agricultural industry chain from 2012 to 2019 in Fig. 5, the intelligent evaluation method under study can obtain the intelligent evaluation results of the whole agricultural industry chain in different years in the study area based on the collected data results of the whole agricultural industry chain. Further analysis of the results of the

**TABLE 4. Intelligent evaluation results of the whole agricultural industrial chain.**

| The secondary indicators | score point |
|---|---|
| Ratio of skilled personnel | 67 |
| High and new technology introduction rate | 75 |
| Standard coverage rate of agricultural products | 81 |
| Product compliance rate | 76 |
| Average agricultural output value | 58 |
| Vegetation coverage rate | 67 |
| Agricultural raw material base scale | 45 |
| Increase rate of added value of agricultural products | 64 |
| Diversity of products | 52 |
| Ability to popularize agricultural technology | 81 |
| Level of agricultural technical popularization | 65 |
| Efficiency of agro-technical extension | 75 |
| Agricultural industrial chain information processing level | 64 |
| Level of logistics informatization | 83 |
| Agricultural industrial chain information dissemination level | 64 |
| Agricultural industrial chain information utilization level | 85 |
| Production capacity of agricultural products | 59 |
| Agricultural industry chain market potential | 71 |
| Agricultural industry chain market ability | 52 |
| Customer service satisfaction | 37 |
| Net return per unit area | 58 |
| Employee income growth rate | 62 |
| Peripheral employment rate increase | 71 |
| Degree of perfection of laws and regulations | 62 |
| The degree of government policy improvement | 75 |
| Risk protection level | 81 |

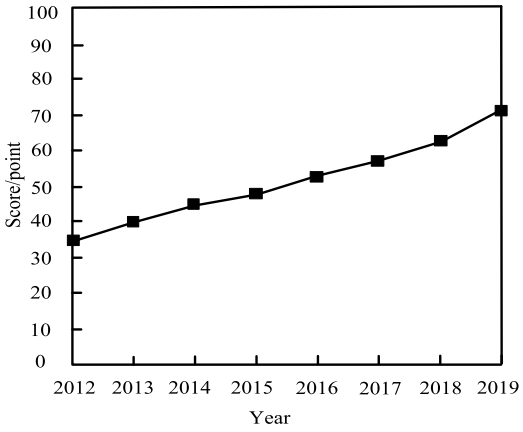


**FIGURE 5. Intelligent evaluation results of the whole agricultural industry chain from 2012 to 2019.**

intelligent evaluation of the whole agricultural industry chain from 2012 to 2019 shows that the evaluation score of the development of the whole agricultural industry chain in the study area from 2012 to 2019 shows an increasing trend year by year, and the study area has gradually realized the importance of the development of the whole agricultural industry chain in recent years. According to the development situation of the whole agricultural industry chain in the research area, a large number of policies to promote the development of the whole industrial chain of agriculture were formulated to promote the development of the whole agricultural industry chain. The development of the whole agricultural industry chain in the study area showed an upward trend year by year.

## V. DISCUSSION

An intelligent evaluation model based on the index system of the whole agricultural industry chain is constructed, and the development of the whole agricultural industry chain in the region is clearly studied by using the constructed model. At present, the development of the whole agricultural industry chain in the study area has been relatively mature, but there are still some problems.

There is no special agricultural information management department and database in China's current agricultural product circulation system, so the information management level is relatively low, and it is difficult to manage the market in time and effectively. Although the information system has basically covered the urban and rural markets and various resources in most areas of our country, it has not fully played its role. At the same time, at present, China lacks mature professionals in the whole agricultural industry chain to conduct theoretical research on the development of agricultural industry. In addition, there are still many scattered resources in agriculture, forestry, animal husbandry and fishery in China, and a complete industrial chain and a perfect industry consolidation have not been formed, resulting in a relatively weak industrial chain. In order to further improve the whole agricultural industry chain of the study region, the following safeguard measures are put forward to promote the development of the whole agricultural industry chain of the study region:

(1) Improve the level of informatization development and standardize the agricultural information platform

In order to further promote the development of the whole agricultural industry chain, the research area should vigorously develop network communication in rural and other remote areas. The development of the whole agricultural industrial chain needs to be connected with scientific research information and industrial chain information in the network. Strengthen the agricultural data platform of the network and the information construction of the agricultural field, give full play to the role of the network, improve the quality of agricultural products, and use the network to realize the supervision of agricultural products. Agricultural production areas need to cooperate with communication enterprises, pay attention to the communication infrastructure construction in remote areas, improve agricultural information; The agricultural information platform needs to have a professional management system, and the Internet of Things and other technologies should be applied to the agricultural information platform, so as to improve the standardization level of information analysis and information release of the agricultural information platform, and standardize the

agricultural information platform by using extremely high operational supervision. Through the standardization of agricultural information platform, promote the further development of the whole agricultural industry chain.

(2) Strengthen the training of agricultural modernization personnel

Agricultural industry development, we should change the traditional agricultural talents cultivation idea, improve the overall level of farming practitioners, formulate the professional personnel training mechanism, cultivating talents, agricultural modernization should build perfect comprehensive agricultural talents cultivation system, give full play to the role of the agricultural universities and agricultural scientific research institution, build the improvement of the agricultural comprehensive talent training system. The government should formulate supportive policies for the cultivation of agricultural talents, encourage rural and other remote areas to vigorously develop the training of agricultural talents, and solve the problem that the development of agricultural training in rural and other remote areas is relatively backward. Managers in rural and remote areas can build a complete cooperation mechanism with financial and other enterprises, attach importance to the role of social capital input, and improve the shortage of agricultural construction funds.

(3) Integrating the main structure of agricultural production

There are many parts of China exist at present agricultural production enterprises, agricultural cooperatives, and many other small organization, the body of the small-scale agriculture organization market competition ability is weak, scientific research and innovation level is poorer, unable to provide support for agriculture industry chain, small-scale agricultural production of agricultural products do not meet the brand standards. Through the integration of small-scale agricultural organizations, the main structure of agricultural production can be optimized, and the defects that agricultural products produced by small-scale agriculture cannot drive regional economy can be improved. The integration of the main structure of agricultural production provides a good environment for the development of agricultural production chain.

(4) To build an information-based agricultural product logistics structure system

In the development process of the whole industrial chain of agricultural products, the efficiency of product circulation is an important content that the government and other departments need to attach great importance to. The informatization construction of the whole agricultural industry chain should not only be reflected in the production and sales of products, but also the informatization construction of product circulation and logistics is more important. Users can use the network to adjust and query the market prices of agricultural products, the existing agricultural market has a higher transparency. Agricultural products use the information platform to realize the docking of sellers and producers, provide convenience for consumers at the same time, improve the production efficiency of agricultural products. In the informatization construction of the whole agricultural industry chain, a quality traceability platform has been set up to track and record the production environment, production process, production quality and other contents of agricultural products, so that consumers can monitor the quality of agricultural products in real time and purchase agricultural products with greater confidence. Agricultural products logistics enterprises can make full use of big data technology, extend the ecological chain of agriculture, take the interests of consumers as the main body, and optimize the development of the whole agricultural industry chain through logistics construction. Agricultural logistics enterprises can actively cooperate with scientific research departments to improve the market conversion rate of agricultural products. Through the level of scientific and technological innovation, the cost of agricultural products will be reduced, so that agricultural enterprises can play a full role in the informatization development level of the whole industrial chain of modern agriculture.

## VI. CONCLUSION

With the continuous improvement of China's agricultural development level, all links of the agricultural industry chain are constantly improved and improved. Blockchain technology, big data technology and many other technologies are applied in the agricultural industry. Through the informatization of the whole agricultural industry chain, all links in the whole agricultural industry chain are closely connected to ensure the development and security of modern agricultural products. By perfecting the whole agricultural industry chain, the level of agricultural development can be improved, and all the components of the whole agricultural industry chain can be maximized. The intelligent evaluation model based on the index system of the whole agricultural industry chain was constructed to intelligently evaluate the indicators within the index system of the whole agricultural industry chain. According to the evaluation results, corresponding improvement measures were formulated to promote the development of the whole agricultural industry chain.

## REFERENCES

[1] J. Zhu, L. I. Xiaojian, D. Wang, and N. Niu, "Study on the evolution of different types of rural functional development in traditional agricultural areas: A case of Xihua in Henan province," *Econ. Geogr.*, vol. 20, no. 1, pp. 149–156, 2019.

[2] H.-P. Yueh and Y.-L. Zheng, "Effectiveness of storytelling in agricultural marketing: Scale development and model evaluation," *Frontiers Psychol.*, vol. 10, pp. 23–28, Mar. 2019.

[3] Y. F. Chen, Y. Liu, and L. I. Yurui, "Agricultural development status and industrial prosperity path under the background of rural revitalization in China," *Geograph. Res.*, vol. 38, no. 3, pp. 632–642, 2019.

[4] J. Pels, L. Araujo, and T. A. Kidd, "Informal sellers and formal markets: A habitus gap," *J. Bus. Ind. Marketing*, vol. 37, no. 6, pp. 1269–1280, May 2022.

[5] S. Lahnamäki-Kivelä, "Coping with uncertainty: Exploring the foresight actions' role in supporting growth-orientation among Finnish dairy farmers," *Futures*, vol. 135, no. 1, pp. 1–13, 2022.

[6] S. Yan and S. Alvi, "Food security in south Asia under climate change and economic policies," *Int. J. Climate Change Strategies Manag.*, vol. 14, no. 3, pp. 237–251, May 2022.

[7] C. L. Goldsmith, K. E. Kang, E. Heitman, Z. N. Adelman, L. W. Buchman, D. Kerns, X. Liu, R. F. Medina, and A. Vedlitz, "Stakeholder views on engagement, trust, performance, and risk considerations about use of gene drive technology in agricultural pest management," *Health Secur.*, vol. 20, no. 1, pp. 6–15, Feb. 2022.
[8] S. Gorucu, B. Weichelt, E. Redmond, and D. Murphy, "Coding agricultural injury: Factors affecting coder agreement," *J. Saf. Res.*, vol. 75, pp. 111–118, Dec. 2020.
[9] M. Pelucha, J. Kourilova, E. Kasabov, and M. Feurich, "Expanding the ontological horizons of rural resilience in the applied agricultural research policy: The case of the Czech Republic," *J. Rural Stud.*, vol. 82, pp. 340–350, Feb. 2021.
[10] C. Deng, C. Liu, X. Sun, L. I. Zhongwu, L. I. Ke, and Y. Wan, "Performance evaluation and difference analysis of cultivated land transfer in heterogeneous typical counties," *Econ. Geogr.*, vol. 39, no. 8, pp. 192–199, 2019.
[11] H. E. Yanzhou and C. Wang, "Evaluation and pattern optimization of rural production space system function: A case study of Banan district, Chongqing municipality," *Econ. Geogr.*, vol. 39, no. 3, pp. 162–171, 2019.
[12] S. Severini, L. Biagini, and R. Finger, "Modeling agricultural risk management policies—The implementation of the income stabilization tool in Italy," *J. Policy Model.*, vol. 41, no. 1, pp. 140–155, Jan. 2019.
[13] S.-H. Liao, D.-C. Hu, and S.-T. Chen, "Supply chain integration, capability and performance—A business-to-business network cooperation," *J. Bus. Ind. Marketing*, vol. 37, no. 5, pp. 1127–1137, Apr. 2022.
[14] L. Fan and P. Wang, "The spatial and temporal evolution of China's wholesale market for agricultural products and it's commodification effect," *Econ. Geogr.*, vol. 39, no. 7, pp. 175–183, 2019.
[15] H. Lan, T. A. Lloyd, S. McCorriston, and C. W. Morgan, "Retailer heterogeneity and price transmission," *Amer. J. Agricult. Econ.*, vol. 104, no. 5, pp. 1679–1700, Oct. 2022.
[16] C. Wang, M. Zhou, L. I. Haoying, H. E. Yanzhou, and M. A. Xiaosu, "Research on the order of rural production space system based on a system entropy model in the dissipative structure," *Geograph. Res.*, vol. 38, no. 3, pp. 619–631, 2019.
[17] K. Hoberg, L. Thornton, and A. Wieland, "Editorial: How to deal with the human factor in supply chain management?" *Int. J. Phys. Distrib. Logistics Manag.*, vol. 50, no. 2, pp. 151–158, Jun. 2020.
[18] C. Gesell, A. H. Glas, and M. Essig, "The impact of buyer–supplier communication on production ramp-up performance," *J. Bus. Ind. Marketing*, vol. 37, no. 5, pp. 945–960, Apr. 2022.
[19] L. T. Liang and K. C. Zhu, "Interregional agricultural eco-compensation based on virtual cultivated land flow: Regional division and compensation standard accounting," *Geograph. Res.*, vol. 38, no. 8, pp. 1932–1948, 2019.
[20] W. Shi, H. Long, and J. Liu, "Identifying problematic areas in the national key regions for ecological function based on the negative list of industry access," *Econ. Geogr.*, vol. 39, no. 8, pp. 12–20, 2019.

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