Research Article

Development and Comprehensive Evaluation of Ecological Agriculture Industry Chain System Based on Genetic Algorithm

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Due to the constraints of traditional agricultural development factors, the existing agricultural industrial chain structure was unreasonable, which can not only promote the development of related industries but also affect the sustainable development of the whole agriculture. Therefore, it was of great significance to build a scientific and orderly ecological agriculture industry chain system and optimize it on the existing basis for improving the industrial benefits of modern agriculture and enhancing the vitality of agricultural development. From the perspective of the construction of an ecological agriculture industry chain system, this study put forward the development and evaluation system of the agricultural industry chain system based on genetic algorithm, in order to provide support for better promoting the development of modern agriculture. First, based on summarizing the related concepts of ecological agriculture and industrial structure, the definition and organization of agricultural industrial chain were given. Second, it expounded the basic theory of genetic algorithm and its application in the optimization of agricultural industrial structure, and put forward the optimization model of ecological agricultural industrial structure combined with the objectives of agricultural industry development. Finally, by constructing the evaluation index system of ecological agriculture industry chain system, a comprehensive evaluation model of ecological agriculture industry chain system based on genetic algorithm was designed. Through the case verification and comparative analysis, the results showed that the ecological agriculture industry chain system evaluation system and evaluation model based on genetic algorithm proposed in this study had certain feasibility and effectiveness, and can better evaluate the changing trend of various industries in the process of agricultural industry development.

1. Introduction

In recent years, with the economic and social development and the continuous progress of human civilization, the agricultural development model has changed from the traditional extensive type to the intensive type [1]. Ecological agriculture is a new agricultural industry developed under the modern ecological concept. It is an organic integration of agriculture, economy, and ecology, and it can promote the continuous development of agriculture in the direction of high efficiency, scale, and economy. With the continuous integration of agricultural industry and market economy, the agricultural industry chain has been widely concerned by relevant personnel and departments. The traditional agricultural industry chain refers to the network structure formed by various industries related to agricultural products, which not only includes agricultural production management departments, crop planting, livestock and poultry breeding, and other industries. However, it also involves other auxiliary intermediate industry departments [2]. As the agricultural industry chain is a collection of related industries formed through the agricultural product chain, it can not only reflect the relevance between industries but also reflect the value and value-added related to industries.

A perfect agricultural industrial chain system is usually an industrial economy with close cooperation between various industries or departments. The interrelationship and

operation management of various industrial links involved have a great impact on the scientific development of the whole industrial chain [3]. At the same time, the construction, improvement, and expansion of the agricultural industrial chain can not only promote the construction of the national economy but also effectively promote the sustainable development of the national economy. Maintaining the orderly development of the agricultural industrial chain is the premise to improve the level of agricultural development. It can not only promote the optimization and adjustment of agricultural industrial structure but also enhance the international competitiveness of agricultural industry.

However, the existing agricultural industry chain still relies on the traditional agricultural production and operation mode, and each link of the agricultural industry chain is not closely connected due to various reasons, which leads to the surplus or unsalable situation of agricultural products, making the whole agricultural industry difficult to meet the needs of social development [4]. At the same time, the composition of the agricultural industry chain is not reasonable, and each department of the industry chain is often divided due to the lack of reasonable distribution of interests, which makes the development of the agricultural industry blocked or difficult to continue. Therefore, starting from the concept and organization of the agricultural industry chain, this article studies the construction of modern agricultural industrial chain, puts forward the objective model of ecological agriculture industry chain system based on genetic algorithm, and establishes a comprehensive evaluation index system in line with the development of ecological agriculture industry chain system, which provides support for optimizing agricultural industry chain and accelerating the development of modern agricultural industry.

2. Related Works

The early stage of agricultural industrial chain originates from industrial economics. It is an economic structure relationship formed by different regions, different agricultural products, and their related industries in the process of certain industrial activities, that is, it consists of three stages: the early stage, the middle stage, and the late stage of agricultural production. In the later stage of agricultural production, agricultural products are used as source materials to implement industrial activities through processing, transportation and sales [5]. The industrial chain can closely link relevant departments with different agricultural products. Through the implementation of various industrial activities for agricultural products, a large industrial chain system can be formed. In the process of economic development, industrial clusters formed by different industrial combinations actually constitute a huge industrial chain system. Among them, the agricultural industry chain is mainly a form of agricultural industry structure composed of agricultural products.

The agricultural industry chain theory is developed by applying the industrial chain theory to the agricultural field based on traditional agriculture. It effectively links the three

processes of agricultural resource supply, product production, and processing, so as to realize the value-added of agricultural products. The research shows that the short and narrow agricultural industrial chain not only can not meet the needs of modern agricultural development but also limits the coordinated development of agricultural production and its related industries [6]. For this reason, some scholars have proposed that properly expanding the agricultural industry chain can not only promote the development of agricultural industry and increase farmers' income, but also further accelerate the development of overall economic construction. Practice has proved that by expanding the industrial chain, we can not only enhance the development power of the industrial chain, but also achieve the goal of optimizing the industrial chain, so as to effectively promote the full use of agricultural resources [7]. In addition, restructuring and optimizing the agricultural industrial chain can enhance the added value of agricultural products to a certain extent, play the role of relevant departments of agricultural production, and promote the balanced development of the whole industry. Some scholars have proposed that the upgrading or transformation of the agricultural industrial chain can not only regulate the construction of the entire industrial chain, but also orderly link up the links related to agricultural production, so that the agricultural industry chain can operate effectively and improve the overall value of the agricultural industry.

With the rapid development of market economy, the organization of agricultural industry chain has changed to some extent. From the traditional single organization to the mixed industrial chain organization [8]. For example, some scholars proposed that the organization of the industrial chain should adopt the agricultural industrial chain organization mode integrating production and sales, and adopt the agricultural production and operation organization cooperation mode, so as to promote the sustainable development of the agricultural industry. In view of the industry chain fault and value chain dislocation in the agricultural industry chain, as well as the problems of low risk prevention ability and weak centralized supervision ability in the process of agricultural industry development, some scholars proposed that the whole industry chain involved in the process from the primary production of agricultural products to the final consumption of users should be established mainly by agricultural leading enterprises [9].

For the setting and optimization of agricultural industrial structure, people often use artificial neural network, support vector machine, and the combination of various prediction methods [10]. By optimizing and adjusting the structure of agricultural industrial chain, the combination of various departments and links of agricultural production can be more scientific and reasonable. Although the artificial neural network can solve the optimization of complex problems, the algorithm does not consider the dynamic changes of multiple factors, resulting in a large difference between the prediction results obtained by the artificial neural network algorithm and the actual values [11]. There are some problems in applying support vector machine algorithm to the analysis and prediction of industrial chain

system. Due to the dynamic change of industrial structure, the convergence time of the algorithm is long, which leads to the poor prediction effect of the development of industrial chain system. In recent years, some scholars began to use genetic algorithm to optimize the structure of agricultural industry chain, and achieved some results.

3. Composition and Organization of Agricultural Industrial Chain

3.1. Concept of Ecological Agriculture. Ecological agriculture is a modern agricultural complex that combines traditional agriculture with modern agriculture according to the theory of ecology and economics, and uses natural and social resources to plan, design and organize agricultural production from the perspective of system engineering. The development of ecological agriculture should not be based on destroying the existing agricultural resources and environment, but on the premise of protecting the existing ecological environment and improving the utilization rate of agricultural resources, through continuously promoting the economic growth of agriculture, improving the rural ecological environment, and realizing the coordinated development of economic, social and ecological benefits, the development of agricultural production and the common progress of people's life, culture and ecological civilization [12]. The development of ecological agriculture can not only reflect the integrity, coordination and circulation of agricultural production process, but also reflect the natural economic development law of agricultural production process.

3.2. Definition of Agricultural Industrial Chain. Industrial chain refers to the chain type relationship structure formed by industrial departments through time-space relations and logical relations based on the interrelationship between technology and economy. For example, in an economic activity, participating enterprises have formed economic and technological relationships among enterprises at different levels according to their respective division of labor or roles. The change of an industrial node may lead to the change of the entire industrial chain [13]. The definition of agricultural industry chain varies from different perspectives. From the perspective of material circulation, agricultural industry chain usually refers to the material connection between industries, from the production, processing, sales to consumption of agricultural and sideline products. From the perspective of department relationship, agricultural industry chain usually refers to the organizational connection between industries, mainly including the interaction between different economic entities such as farmers, associations, processing enterprises, and retailers.

Compared with the traditional agricultural industrial chain, the modern ecological agricultural industrial chain involves more disciplines and fields, including not only agronomy, pharmacology, and management, but also different professional knowledge such as agricultural product processing, packaging design, and marketing. Therefore, the ecological agriculture industry chain is a comprehensive industrial system. Moreover, the construction of ecological agriculture industry chain needs to be planned according to the specific conditions of different regions. In fact, the agricultural industry chain is an industrial structure that takes agricultural products as the object and organizes the relevant links such as production, sales, processing and logistics, including all periods and relevant departments in the process of agricultural industry development. As shown in Figure 1, the overall structure of the agricultural industry chain is described.

As a new form of industrial composition, modern ecological agriculture industry chain is a complex system composed of many elements with large scale and network structure. Modern ecological agriculture industry chain usually includes logistics chain, information chain, value chain, and organization chain [14]. It not only covers the whole field of agricultural production, but also involves the production, processing, circulation and consumption of agricultural products. The industrial chain of modern ecological agriculture not only includes the main chain composed of different links, but also includes several secondary chains in each link. Each link in the main chain corresponds to the relevant functions in the field of agricultural production. Among them, the implementation subjects of these functions include farmers, enterprises, associations, and service institutions.

3.3. Organization of Agricultural Industrial Chain. According to the space-time characteristics of modern agricultural industrial chain and the connection mode between different nodes of the industrial chain, the organization mode of agricultural industrial chain has many different forms. If we ignore the specific internal relationship between the node enterprises of the agricultural industry chain, we can classify the organization mode of the modern agricultural industry chain according to the vertical connection between the enterprises that constitute the chain nodes.

According to the existing classification methods, most of the organizational models of agricultural industry chains are classified from the two-dimensional perspective of agricultural development. The first dimension refers to the vertical connection of the participants in the agricultural industry chain, that is, the organizational model of the agricultural industry chain is classified according to the connection of the participants. When there is a cooperative relationship between the participants, no matter what connection mechanism is adopted between them, the connection between the participants has a certain binding force. The second dimension is the range of the vertical connection relationship between the participants in the industrial chain, that is, the number of enterprises participating in the vertical constraints [15]. If all the participants in the agricultural industrial chain have mutual constraints, then the participants in the industrial chain are called overall cooperation, or local cooperation. As shown in Figure 2, it is the organization mode classification of modern agricultural industry chain.
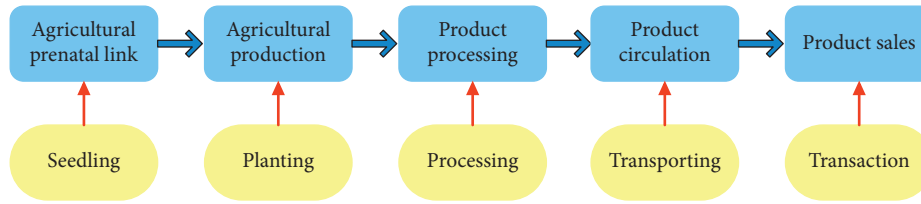
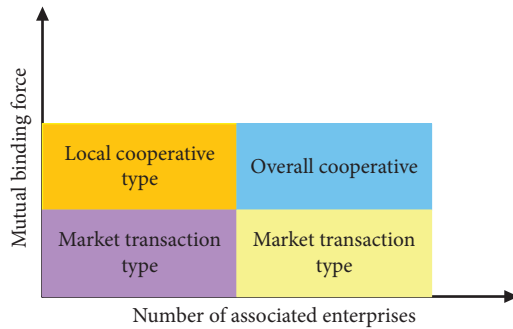FIGURE 1: Composition diagram of agricultural industrial chain structure.

FIGURE 2: Classification diagram of agricultural industrial chain organization methods.

From a two-dimensional perspective, the agricultural industry chain organization modes can be classified into three common types of agricultural industrial chain organization modes, as shown in Figures 3–5. The participants included in the dotted ellipse are all members of the industrial alliance.

From the existing industrial chain organization mode, the market transaction industrial chain is the most basic agricultural industrial chain organization mode. All participants in the industrial chain trade through the market, and there is generally no cooperative relationship between participants. Therefore, it belongs to the non-cooperative agricultural industrial chain organization mode [16]. As shown in Figure 3, the agricultural industry chain organization mode of market transaction type is described. From the connection between the participants, it can be seen that most of the market transactions between the participants are completed through paper contracts or oral contracts. Therefore, the vertical links between the participants are not binding, that is, they do not have a cooperative relationship.

When the participants in the agricultural industrial chain have a certain binding force, whether they are connected through contract, property rights or other ties, it indicates that they have cooperative relations. The industrial chain organization model formed from this is a cooperative agricultural industrial chain. As shown in Figure 4, the cooperative agricultural industry chain organization mode is described.

From the perspective of the second dimension, when all participants in the agricultural industrial chain have vertical links with each other, the industrial chain model is an overall cooperative agricultural industrial organization model. However, when some participants in the agricultural industrial chain are binding, the industrial chain model is a

local cooperative agricultural organization model, as shown in Figure 5.

4. Evaluation of Ecological Agriculture Industry Chain Based on Genetic Algorithm

4.1. Theoretical Basis of Genetic Algorithm. As a commonly used global optimization algorithm, genetic algorithm has the characteristics of simple, universal, robust and suitable for parallel processing. It is one of the most widely used intelligent optimization algorithms. Genetic algorithm is an iterative search algorithm formed in the process of continuous generation and detection, which has been preliminarily applied to the optimization and adjustment of agricultural industrial chain structure. It is a group type processing process that takes all individuals in the population as objects. Genetic algorithm mainly uses selection, crossover and mutation as the main operators and constitutes the genetic operation of the algorithm, which is also a feature that other traditional methods do not have. Genetic algorithm usually contains five basic elements: parameter coding, population initialization, fitness function and design of genetic operation, population size and probability of using genetic operation [17]. These elements are the core of genetic algorithm.

For the n-dimensional decision vector $D = [d_1, d_2, \ldots, d_n]^T$ that needs to be optimized, the symbol string D composed of n symbols D_k, $k = 1, 2, \ldots, n$, which may be used to describe it, as follows:

$$D = [d_1, d_2, \ldots, d_n]^T \Leftrightarrow D = D_1 D_2 \ldots D_n. \tag{1}$$

If D_k is regarded as a genetic gene and all its possible values are called alleles, D can be regarded as a chromosome or individual composed of n genetic genes. The most basic method to encode chromosomes is the symbol string expressed in binary form. After encoding, the arrangement form is considered as the genotype of the individual, and the value of the corresponding decision variable is considered as the phenotype of the individual. For all individuals D, fitness needs to be calculated according to certain rules. Fitness has a certain correlation with the objective function of its corresponding individual phenotype D. When D is closer to the best point of the objective function, its fitness is larger, on the contrary, its fitness is smaller. The set of decision variables D constitutes the solution space of the problem to be optimized. By searching the space composed of all chromosomes, that is, searching the set composed of multiple decision variables, the optimal solution of the problem to be optimized can be obtained.
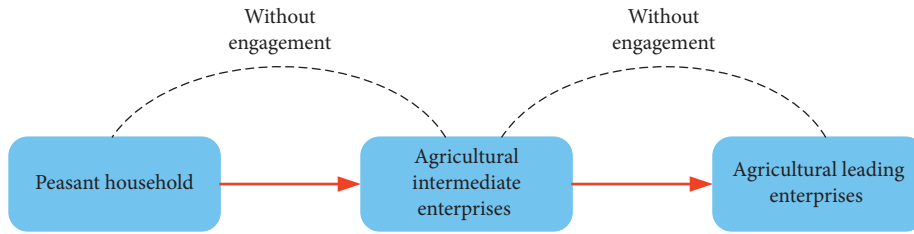
FIGURE 3: Schematic diagram of the construction of market trading agricultural industry chain.
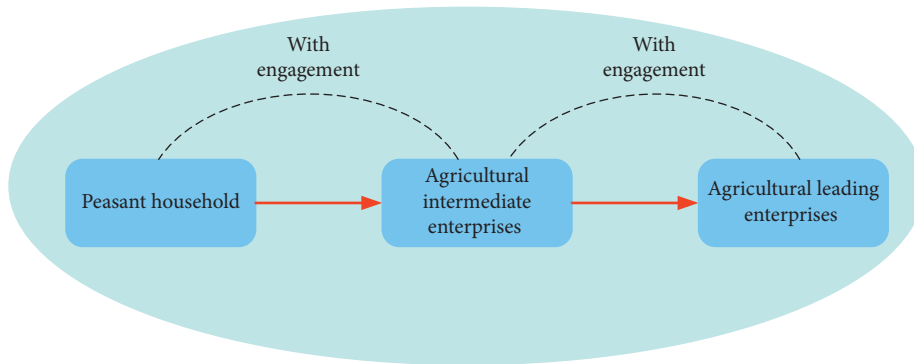

FIGURE 4: Schematic diagram of overall cooperative agricultural industry chain construction.
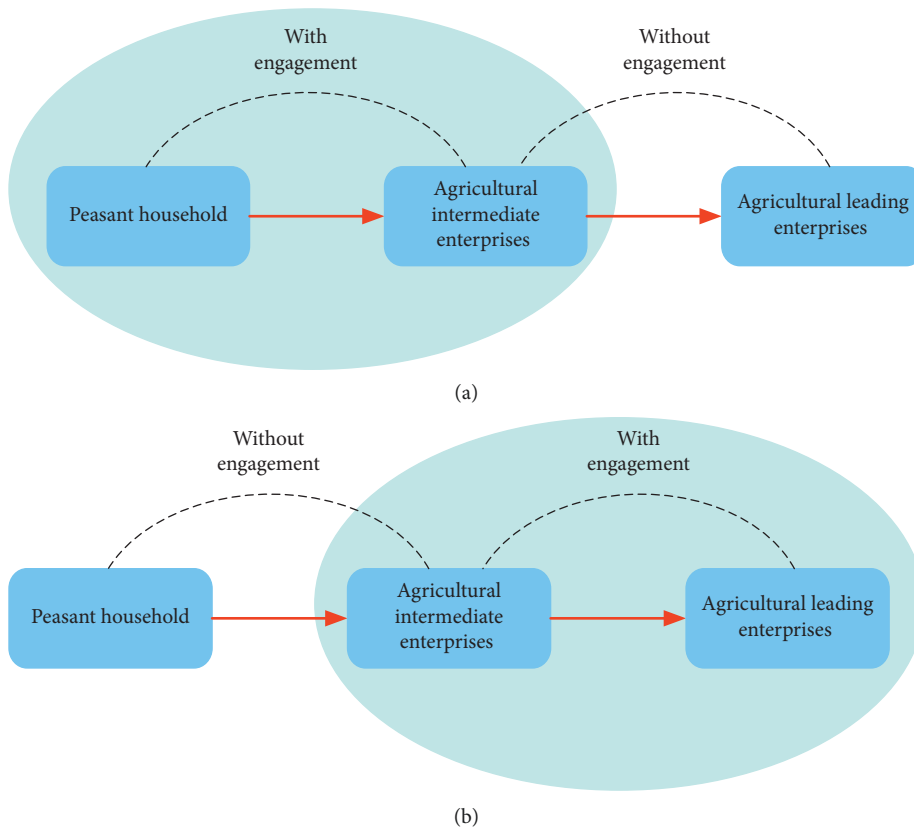

(a)

(b)

FIGURE 5: Schematic diagram of construction of local cooperative agricultural industry chain.

The object that the genetic algorithm deals with is a group composed of several individuals. The implementation of the algorithm is a process of repeated iteration [18]. If the population of generation m is expressed as $p(m)$, after the first generation genetic processing, that is, through the operation of chromosome selection, crossover and

mutation, the population of generation $m + 1$ can be obtained, which is expressed as $p(m + 1)$. Then, genetic and evolutionary processing operations are carried out on this population. Each time, individuals with high fitness are inherited to the next generation according to the rules of survival of the fittest. Finally, the excellent individual is D. The phenotype D of this individual is the optimal solution of the problem.

During the execution of genetic algorithm, many individuals who participate in the operation at the same time form a population. After encoding individuals, the population needs to be initialized, and then the individuals are evolved generation by generation until the last generation or the population terminates evolution. In genetic algorithm, the individuals constituting the initial population are usually randomly generated [19]. In order to solve the problem, the initial population can be adjusted appropriately. For example, some people set the distribution range of the optimal solution in the whole problem space according to the characteristics of the problem, and set the initial group within this range. Some scholars randomly generate some individuals and add the best individuals to the initial population. Through the continuous iteration of genetic operation, the number of individuals in the initial population can be increased to a certain scale.

Fitness is mainly used to express the degree to which an individual approaches the optimal solution of the problem. It is the basis for genetic algorithms to optimize. The fitness function needs to be sorted by comparison and thus the selection probability is calculated. Therefore, the value of the fitness function is generally positive. According to the actual application, the objective function can be converted to the maximum value form. The construction of the fitness function is determined by the problem to be solved. Taking the solution of the optimization problem as the goal, the fitness function $G(D)$ of the individual is calculated according to certain rules with the objective function $g(D)$ as the independent variable. The specific calculation formula is as follows:

$$G(D) = \begin{cases} R_{\text{Max}} - g(D), & R_{\text{Max}} - g(D) > 0, \\ 0, & R_{\text{Max}} - g(D) \le 0, \end{cases} \quad (2)$$

where R_{Max} is a relatively large number that can be selected in different ways, and R_{Max} is generally independent of the population. For the maximization problem, the conversion formula is as follows:

$$G(D) = \begin{cases} R_{\text{Min}} + g(D), & R_{\text{Min}} + g(D) > 0, \\ 0, & R_{\text{Min}} + g(D) \le 0, \end{cases} \quad (3)$$

where R_{Min} is a relatively small number that can be selected in different ways.

In the process of genetic algorithm implementation, in order to maintain the diversity of individuals in the population, it is usually necessary to scale the fitness of individuals in the later stage of evolution to avoid premature convergence [20, 21]. The common methods of scaling fitness in practical applications mainly include linear, power, and exponential operations.

4.2. Optimization Model of Ecological Agriculture Industry Structure.

The industrial structure of ecological agriculture is composed of various departments within the agricultural industry and their mutual relations. It can not only reflect the internal relationship among planting, breeding, and forestry, but also establish the relationship between the agricultural products of these industries. In a broad sense, the industrial structure of ecological agriculture involves the agricultural industrial structure of different regions [8]. In recent years, the industrial structure of ecological agriculture has the following characteristics: first, the formation of the industrial structure of ecological agriculture is determined by objective conditions with the economic development. Second, the industrial structure of ecological agriculture is a whole organically related through relevant departments, and each department plays a certain role in the agricultural industrial system. Third, the ecological agriculture industry structure includes several different hierarchical structures. For example, agriculture, forestry, animal husbandry, and fishery constitute the primary structure of the ecological agriculture industry, and different primary structures are divided into several corresponding secondary structures according to their product attributes and production characteristics. By analogy, the agricultural industry structures at different levels play a certain role in agricultural production. Fourth, the industrial structure of ecological agriculture usually changes with the economic and social development and demand changes.

In order to maintain the stability and sustainable development of the ecological agriculture industry chain system, the ecological agriculture industry structure usually requires that all agricultural departments, production projects, and products maintain a certain proportion relationship, so as to maximize the use of existing human and material resources and achieve the orderly and healthy development of agricultural production on the premise of maintaining ecological balance.

Generally speaking, whether the industrial structure of ecological agriculture can achieve sustainable development can be judged by such indicators as the development and utilization rate of existing agricultural resources, the maintenance and improvement degree of ecological environment, the level of economic benefits, and the coordination of various agricultural departments. By continuously improving and optimizing the ecological environment and reasonably adjusting the agricultural industrial structure, we can not only effectively improve the conversion rate between biology and the environment, but also continuously improve agricultural output. A large number of practices show that the rationality of agricultural industry structure can be measured by economic benefits. Only through mutual promotion and coordination can agricultural departments realize the sustainable development of the whole ecological agricultural industrial system.

In a broader sense, the composition of the ecological agriculture industry chain mainly includes planting, animal husbandry, forestry, and aquaculture. The setting of the industrial structure of ecological agriculture needs to consider the optimization of the distribution of various industries and the improvement of ecology. Through the improvement of the industrial structure of ecological agriculture and related measures, the coordinated development of the economic, ecological, and social benefits of the agricultural industry can be realized.

In order to describe the change in ecological agriculture industry structure, decision variables can be used to measure the change trend of different industries [22]. Decision variables are mainly composed of production projects in different industries. For example, planting takes the planting area of various crops as the decision variable, animal husbandry takes the stock of various livestock and poultry as the decision variable, forestry takes the planting area of different forest species and tree species on different lands as the decision variable, and aquaculture takes the feeding scale of various aquatic products as the decision variable.

The set of decision variables may be described as follows:

$$D = \left\{ D_{kj} \right\} \quad k = 1, 2, \ldots, N, \tag{4}$$

where D_{kj} represents the j-th decision variable of the k-th industrial sector, while k refers to different types of agricultural industries. For example, D_{1j} refers to the planting area of the j-th crop in the planting industry, D_{2j} refers to the stock of the j-th livestock and poultry in the animal husbandry, D_{3j} refers to the planting area of the j-th forest species and tree species in the forestry, and D_{Nj} refers to the planting area of the j-th aquatic product in the aquaculture industry.

The goal of optimizing the ecological agriculture industry chain is to ensure the coordinated development of economic, social, and ecological benefits. When determining the target, we should not only consider the maximization of economic benefits of various industries, but also take into account regional water and soil conditions, soil fertility, green coverage area, and other ecological indicators. At the same time, the development of ecological agriculture industry must ensure that the output of agricultural products can meet the needs of residents to the greatest extent, and achieve certain social benefits by improving people's living standards and quality.

The overall economic benefit objective function of the ecological agriculture industry can be expressed as follows:

$$
\begin{aligned}
\mathrm{Max}\, E(D) = & \sum_{k=1}^{N} \sum_{j \in U_k} H_{kj} D_{kj} \\
& + \sum_{j \in U_1} \left[\omega_j \lambda_j \ln \left(1 + \mu_j D_{1j} \right) + \left(1 - \omega_j \right) \frac{\lambda_j}{1 + \mu_j e^{D_{1j}}} \right],
\end{aligned}
\tag{5}
$$

where $E(D)$ represents the total net income of relevant industries. H_{kj} indicates the unit net output value of the j-th decision variable in the k-th industry. U_k is the indicator set of each sector of the k-th industry. ω_j denotes the corresponding weight coefficient. λ_j and μ_j represent the corresponding estimation parameters in turn.

Ecological protection and the maintenance of ecological balance are the basic conditions for the sustainable development of agricultural industry. Since ecological indicators are difficult to quantify, they are mainly expressed by constraints in the setting of ecological agriculture industry structure [23]. As the soil moisture and nutrients directly affect the development of agricultural production, vegetation coverage, animal husbandry, and aquaculture, the content of soil organic matter can be taken as an important parameter for the construction of ecological objective function, so as to reflect the constraints such as water and soil conservation and green coverage area.

The calculation model of soil organic matter content is as follows:

$$\mathrm{Min}\varphi(D) = X - \left[\frac{WV}{Q} - \left(\frac{WV}{Q} - X_0 \right) \cdot e^{KT} \right], \tag{6}$$

where $\varphi(D)$ represents the difference of soil organic matter content. X indicates the content of organic matter in the balanced utilization state of the soil. Q is the mineralization rate of soil organic matter. W denotes the soil decay rate. V is the ratio of organic fertilizer in soil. X_0 indicates the initial value of organic matter content in soil.

In order to better meet people's demand for agricultural products, the social benefits of agricultural products mainly include the commodity rate, total output value, per capita share and per capita consumption level of agricultural products. Generally, meeting people's demand for agricultural products to the greatest extent is an important symbol to judge the rationality of agricultural industrial structure. Therefore, the minimum shortage of agricultural, livestock and aquatic products can be used as the target model of social benefits, and its calculation formula is as follows:

$$\mathrm{Min}\nu(D) = \sum_{k=1}^{N} \sum_{j \in U_k} \left(L_{kj} - M_{kj} \cdot D_{kj} \right) S_{kj}, \tag{7}$$

where S_{kj} represents the difference in social expectations for agricultural products. L_{kj} indicates the social demand for agricultural products of the j-th class of the k-th industry sector. M_{kj} is the output of agricultural products of the j-th class per unit area. S_{kj} denotes the social demand coefficient for agricultural products of the j-th class of the k-th industry sector.

4.3. Comprehensive Evaluation Index System of Ecological Agriculture Industry. The ecological agriculture industry chain system includes agricultural economy, technology, ecology, rural society, and other systems at all levels. There are certain interactions and influences among subsystems at all levels. The development of the ecological agriculture industry chain system cannot be separated from the high coordination of these subsystems. The sustainable development of ecological agriculture industry is related to the development level of local agricultural production [24].
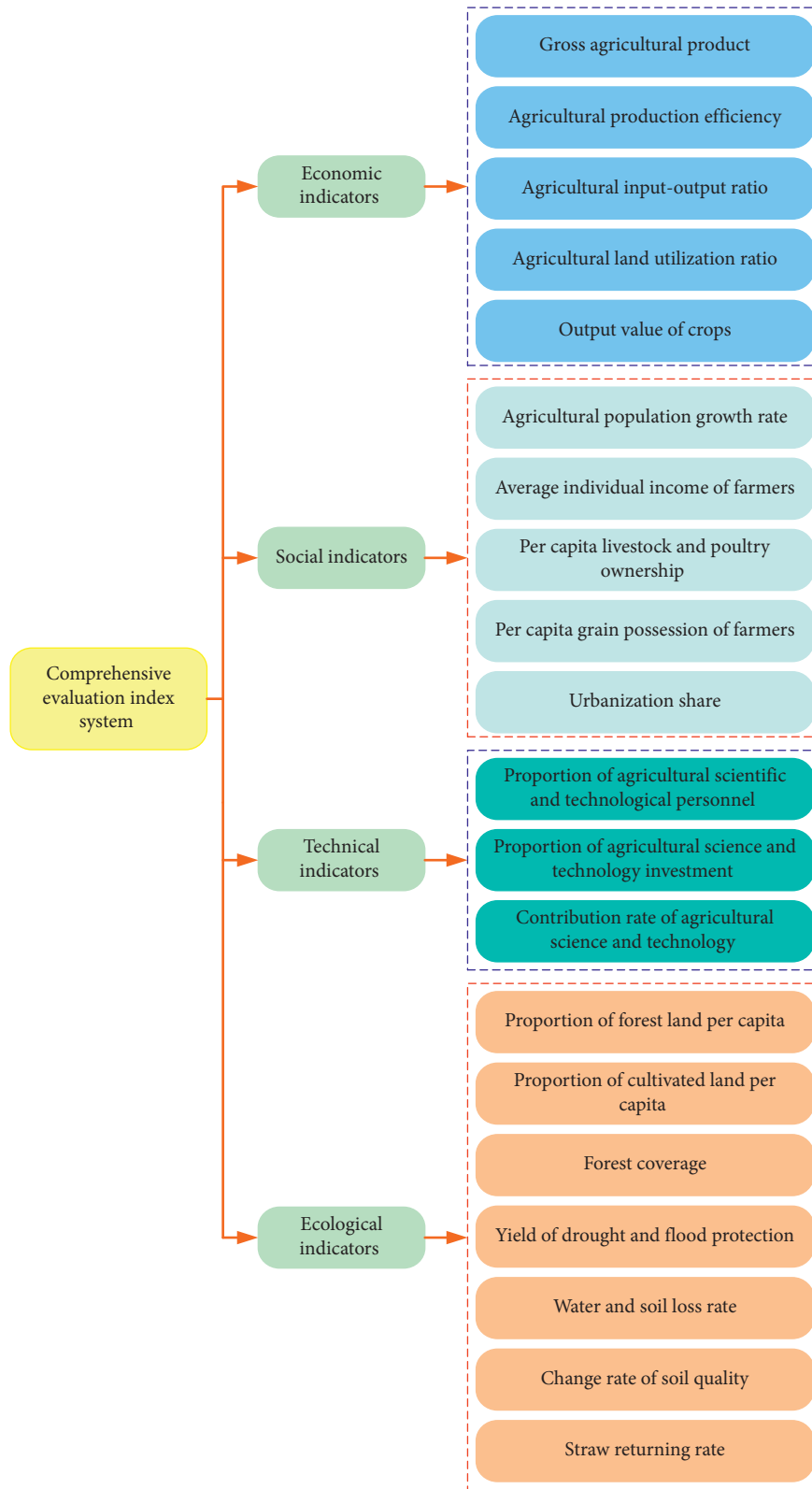
FIGURE 6: Schematic diagram of construction of comprehensive evaluation index system for the development of ecological agriculture industry chain system.

Among them, the level of agricultural production is determined by the coordination of the elements of agricultural ecosystem, and the agricultural production capacity is determined by the supporting system of local agricultural production development. In order to comprehensively evaluate the development of the ecological agriculture

industry chain system, it is necessary to build an index system to reflect the development of agricultural production, and evaluate the relationship between the subsystems in the agricultural industry system.

On the premise of conforming to the evaluation principles of agricultural industrial structure and its adjustment, some basic principles should be followed in the construction of the evaluation index system of ecological agricultural industrial system. First of all, the evaluation index system should be formulated according to the local conditions and time to make it hierarchical, systematic and scientific. Second, the evaluation indicators are dynamic and stable, which can not only reflect the basic state of agricultural resources, ecology and economic society, but also reflect the dynamic development process of each subsystem. Finally, the evaluation indicators not only have certain comparability but also can effectively obtain the information related to the evaluation indicators.

According to the above basic principles for constructing the evaluation index system of the ecological agriculture industry system, from the perspective of the development of the ecological agriculture industry, the ecological agriculture industry system is divided into four different secondary subsystems: economy, technology, environment, and society. At the same time, the system takes into account the index parameters involved in the relevant objective models of the ecological agriculture industry system.

As shown in Figure 6, it is the composition diagram of the evaluation index system of the ecological agriculture industry system.

4.4. Comprehensive Evaluation Model of Ecological Agriculture Industry Chain System Based on Genetic Algorithm. In genetic algorithm, for solving and optimizing complex problems, it is difficult to reflect the changes of agricultural industry structure by using traditional binary vectors. Therefore, the population stability of mutation operation can be realized by using real number coding method, which represents each chromosome as a floating-point vector. In genetic algorithm, because the individuals of the initial population are mainly generated randomly, the variables involved in the objective function generally expand the distribution range of variables by increasing the problem space. As long as the search space is provided, the convergence speed of genetic algorithm is relatively fast. Therefore, each variable in the system should belong to a different interval, and the initial population can be generated randomly in the interval. At the same time, when using genetic algorithm to optimize multi-objective problems, we need to use multiple objectives to determine the individual fitness. In addition, the current population information can be used to adjust the weight [18, 19]. When optimizing the ecological agriculture industry chain system, the objective function can be transformed into a maximization problem with n objectives. The calculation model of weight and objective function is as follows:

$$\text{Obj}(D) = \sum_{k=1}^{n} \omega_k g_k(D) = \sum_{k=1}^{n} \frac{g_k(D)}{\text{Obj}_{k\max} - \text{Obj}_{k\min}}, \quad (8)$$

where $\text{Obj}_{k\max}$ and $\text{Obj}_{k\min}$ are the maximum and minimum values of the k-th target $g_k(D)$ of the existing object.

In the evaluation index system of ecological agriculture industry chain system, in order to describe the impact of index changes on the development of ecological agriculture industry chain system, the following model can be used to evaluate individual indicators:

$$\text{EV}_{kj}(T) = \frac{D_{kj}(T)}{D_{kj}(T_0)}, \quad (9)$$

where $\text{EV}_{kj}(T)$ is the evaluation value of indicator $D_{kj}(T)$ and $D_{kj}(T_0)$ is the flag value of $D_{kj}(T)$.

The comprehensive evaluation model of the ecological agriculture industry chain system can be obtained by weighting and summing each index point, as shown below:

$$E_k(T) = \sum_{j=1}^{M} \omega_{kj}\text{EV}_{kj}(T), \quad k = 1, 2, \ldots, N,$$

$$E(T) = \sum_{k=1}^{N} \omega_k \text{EV}_k(T), \quad (10)$$

where $E_k(T)$ refers to the comprehensive evaluation value of the subsystem in year T, and $E(T)$ is the comprehensive evaluation value of the development of the ecological agriculture industry chain system in year T, $E(T)$ represents the weight of the k-th index of subsystem and ω_k denotes the weight of the k-th subsystem.

5. Experiment and Analysis

In order to comprehensively evaluate the model of ecological agriculture industry chain system based on genetic algorithm proposed in this paper, an ecological agriculture industry chain system in southern China was selected for experiment. In order to facilitate comparison, the basic data of agricultural industry structure before and after 2015 are taken as the objects for statistical analysis. Among them, the industrial structure has not been adjusted before 2015 but has been adjusted after 2015.

Using the evaluation index system of the ecological agriculture industry chain system constructed in this paper, and based on the analysis of the system emergy flow, the four emergy indexes of the ecological agriculture industry chain system, namely, Ratio of renewable input (R), Energy yield ratio (EYR), Environmental loading ratio (ELR) and Feedback yield ratio (FYR), are calculated.

The ratio of renewable input (R) of the system mainly reflects the utilization rate of renewable resources of the ecological agriculture industry system, which is used to evaluate the renewable and sustainability of the ecological agriculture system. The greater the value, the higher the renewable and sustainability of the system.

The system emergy yield ratio (EYR) mainly reflects the input level required for the development of local agricultural production resources, and is used to evaluate the production efficiency of the ecological agriculture system. The greater the value, the higher the agricultural production efficiency.
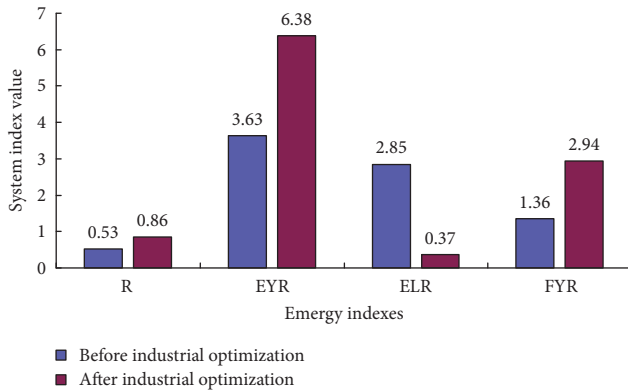
FIGURE 7: Comparison results of system emergy before and after optimization of ecological agriculture industry industry.
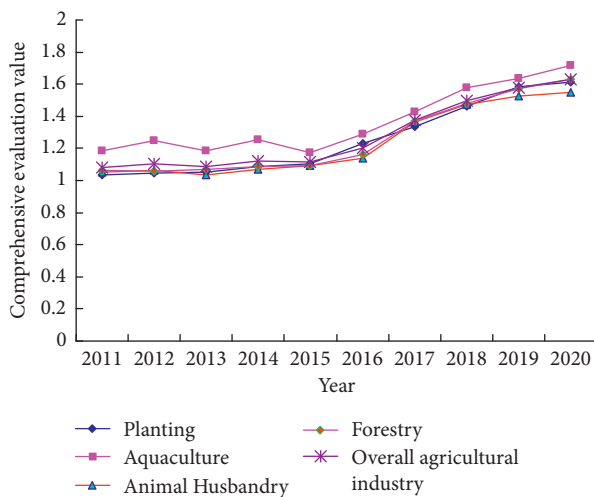

FIGURE 8: Comprehensive evaluation results before and after optimization of each subsystem of ecological agriculture industry chain.

The environmental loading ratio (ELR) mainly reflects the environmental load by using the ratio of the system non-renewable emergy input to the renewable emergy input. The greater the value, the more serious the damage of agricultural production to the environment.

The system feedback yield ratio (FYR) mainly uses the ratio of the system output energy to the socio-economic system feedback emergy to reflect the self-adaptability of the agricultural ecological industry chain system. The larger the value, the stronger the self-adaptability of the system.

As shown in Figure 7, the comparison results of system emergy before and after the optimization of ecological agriculture industry in the region are shown.

In order to compare the development of the ecological agriculture industry chain system in this region, the comprehensive evaluation index system constructed in this paper is used to evaluate and analyze the subsystems of the ecological agriculture industry chain. During the experiment, the comprehensive evaluation values before and after the optimization of the ecological agriculture industry in the region were compared. Among them, the evaluation results

before the optimization of the agricultural industry in the region were from 2011 to 2015, and the evaluation results after the optimization of the agricultural industry in the region were from 2016 to 2020.

As shown in Figure 8, it shows the comprehensive evaluation results before and after the optimization of each subsystem of the ecological agriculture industry chain in the region.

Compared with the agricultural industry chain system before 2015, after the adjustment and optimization of the industrial structure of ecological agriculture, the comprehensive ability of sustainable development of agricultural industry in the region has been gradually strengthened after 2016. From the above evaluation results of each index of each subsystem of the agricultural industrial chain, we can know that the comprehensive evaluation index system of the industrial structure of Ecological Agriculture established in this paper and the development target value of the industrial system obtained by genetic algorithm can effectively reflect the development law and trend of local ecological agriculture.

6. Conclusion

In view of the unreasonable structure of the existing agricultural industry chain and other problems that affected the sustainable development of agriculture, this paper put forward the evaluation system and comprehensive evaluation model of the ecological agriculture industry chain system based on genetic algorithm from the perspective of the scientific development of the agricultural industry chain system. By outlining the concept of ecological agriculture and related industrial structure, this study expounded the composition and organization mode of agricultural industrial chain. At the same time, the basic theory of genetic algorithm and its significance to the optimization and adjustment of agricultural industry structure were summarized, and the optimization model of ecological agriculture industry structure was put forward according to the development goal of agricultural industry. In addition, based on constructing the evaluation index system of ecological agriculture industry chain system, a comprehensive evaluation model of ecological agriculture industry chain system based on genetic algorithm was proposed. Finally, from the results of case verification and comparative analysis, it can be seen that the evaluation system and evaluation model of ecological agriculture industry chain system based on genetic algorithm proposed in this paper can better evaluate the change trend of various industries in the process of agricultural industry development. This study had certain reference value and significance for improving the level of modern agricultural industry and enhancing the power of agricultural development. Considering the huge and complex agricultural industry system, it is necessary to carry out in-depth research on the optimization of the industrial chain structure of ecological agriculture in combination with the relationship between agricultural industry and other industries in the future.

Data Availability

The labeled data set used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

References

[1] L. Gokhberg, I. Kuzminov, A. Chulok, and T. Thurner, "The future of Russia's agriculture and food industry between global opportunities and technological restrictions," *International Journal of Agricultural Sustainability*, vol. 15, no. 4, pp. 457–466, 2017.

[2] Q. Shuo, "Construction of the industry chain of ecological agriculture combined with big data," *Agro Food Industry Hi-Tech*, vol. 28, no. 1, pp. 2499–2503, 2017.

[3] P. Tittonell, "Ecological intensification of agriculture - sustainable by nature," *Current Opinion in Environmental Sustainability*, vol. 8, pp. 53–61, 2014.

[4] F. B. Shang and W. J. Zhu, "Planning of ecological agricultural tourist attractions based on the concept of circular economy," *Acta Agriculturae Scandinavica Section B Soil and Plant Science*, vol. 72, no. 1, pp. 538–552, 2022.

[5] W. Zhou, "The compensation standard of eco-environmental cost in agricultural industry in China," *Journal of Coastal Research*, vol. 104, no. sp1, pp. 665–669, 2020.

[6] R. C. Kasana and C. B. Pandey, "Exiguobacterium: an overview of a versatile genus with potential in industry and agriculture," *Critical Reviews in Biotechnology*, vol. 38, no. 1, pp. 141–156, 2018.

[7] L. F. Jia, "Research on remote training system of eco - agriculture based on cloud computing," *Agro Food Industry Hi-Tech*, vol. 28, no. 3, pp. 2657–2660, 2017.

[8] Z. X. Xiong and H. Li, "Ecological deficit tax: a tax design and simulation of compensation for ecosystem service value based on ecological footprint in China," *Journal of Cleaner Production*, vol. 230, pp. 1128–1137, 2019.

[9] W. Shan, "Ecological environment protection and agricultural regional economic development in the yellow river basin," *Journal of Environmental Protection and Ecology*, vol. 22, no. 5, pp. 2241–2250, 2021.

[10] U. Akbar, Q. L. Li, M. A. Akmal, M. Shakib, and W. Iqbal, "Nexus between agro-ecological efficiency and carbon emission transfer: evidence from China," *Environmental Science & Pollution Research*, vol. 28, no. 15, pp. 18995–19007, 2021.

[11] S. L. Levine, J. Giddings, T. Valenti, G. P. Cobb, D. S. Carley, and L. L. McConnell, "Overcoming challenges of incorporating higher tier data in ecological risk assessments and risk management of pesticides in the United States: findings and recommendations from the 2017 workshop on regulation and innovation in Agriculture," *Integrated Environmental Assessment and Management*, vol. 15, no. 5, pp. 714–725, 2019.

[12] L. X. Dong, "Toward resilient agriculture value chains: challenges and opportunities," *Production and Operations Management*, vol. 30, no. 3, pp. 666–675, 2021.

[13] S. S. Kamble, A. Gunasekaran, and S. A. Gawankar, "Achieving sustainable performance in a data-driven agriculture supply chain: a review for research and applications," *International Journal of Production Economics*, vol. 219, pp. 179–194, 2020.

[14] L. S. Sun, B. C. Su, and Q. Wang, "Marine agriculture development and management from the perspective of supply chain and transaction costs," *Journal of Coastal Research*, vol. 112, no. sp1, pp. 237–239, 2020.

[15] R. Sharma, S. S. Kamble, and A. Gunasekaran, "Big GIS analytics framework for agriculture supply chains: a literature review identifying the current trends and future perspectives," *Computers and Electronics in Agriculture*, vol. 155, pp. 103–120, 2018.

[16] M. Day and N. Vink, "The distortions to incentives in South African agriculture: a case study of the wheat industry," *Agrekon*, vol. 58, no. 3, pp. 292–307, 2019.

[17] Y. W. Zhou and H. H. Fan, "Research on multi objective optimization model of sustainable agriculture industrial structure based on genetic algorithm," *Journal of Intelligent and Fuzzy Systems*, vol. 35, no. 3, pp. 2901–2907, 2018.

[18] Indu, R. P. Singh, H. R. Choudhary, and A. K. Dubey, "Trajectory design for UAV-to-ground communication with energy optimization using genetic algorithm for agriculture application," *IEEE Sensors Journal*, vol. 21, no. 16, pp. 17548–17555, 2021.

[19] Y. Y. Song, F. L. Wang, and X. X. Chen, "An improved genetic algorithm for numerical function optimization," *Applied Intelligence*, vol. 49, no. 5, pp. 1880–1902, 2019.

[20] L. N. Bi and G. P. Hu, "A genetic algorithm-assisted deep learning approach for crop yield prediction," *Soft Computing*, vol. 25, no. 16, pp. 10617–10628, 2021.

[21] S. Elsoragaby, A. Yahya, M. R. Mahadi et al., "Applying multi-objective genetic algorithm (MOGA) to optimize the energy inputs and greenhouse gas emissions (GHG) in wetland rice production," *Energy Reports*, vol. 6, pp. 2988–2998, 2020.

[22] J. S. Huang and J. Song, "Optimal inventory control with sequential online auction in agriculture supply chain: an agent-based simulation optimisation approach," *International Journal of Production Research*, vol. 56, no. 6, pp. 2322–2338, 2018.

[23] L. P. Catala, M. S. Moreno, A. M. Blanco, and J. A. Bandoni, "A bi-objective optimization model for tactical planning in the pome fruit industry supply chain," *Computers and Electronics in Agriculture*, vol. 130, pp. 128–141, 2016.

[24] L. A. Lopez, M. A. Cadarso, N. Gomez, and M. A. Tobarra, "Food miles, carbon footprint and global value chains for Spanish agriculture: assessing the impact of a carbon border tax," *Journal of Cleaner Production*, vol. 103, pp. 423–436, 2015.