Evaluation of Scale Effect of Fragmented Agricultural Land Transfer Based on Neural Network

Lingjuan Tai[1], Linhong Li[1], Jun Du[2]*

ABSTRACT

The artificial neural network consists of a large number of neurons interconnected to each other, which simulates the information process mode of human brains. This is a complex network system that carries out parallel processing of information and nonlinear transformation. The agricultural land in China is characterized by fine fragmentation, and people-land relation is tense. In order to promote the intensive development of agriculture in China, this paper takes 31 provinces and cities as research objects and proposes an evaluation model based on adaptive fuzzy neural network (ANFIS) for the scale effect of fragmented agricultural land transfer to overcome the subjectivity of traditional evaluation methods. In order to improve the accuracy of the evaluation, the combination of qualitative and quantitative methods is used to screen the indicators, and the subtraction clustering method is used to obtain the initial fuzzy rules of the adaptive fuzzy neural network. Then, the adaptive fuzzy neural network model can be trained and tested and the convergence results of the model are good. The results of model analysis show that under different resource endowments and production conditions, the scale effect of land transfer in different regions presents significant differences. On this basis, it is proposed that the intensification process of the agricultural land use cannot be blindly promoted, and the land transfer should follow the principle of moderation. Appropriate agricultural production models should be formulated based on different geographical environments.

Key Words: Agricultural Land Transfer, Evaluation of Scale Effect, Subtractive Clustering, Adaptive Neural Network

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Introduction

Fragmented agricultural land is one of the main characteristics of traditional agricultural production in China (Chen *et al*., 2011). In history, apart from the phase of "collectivization of agriculture" and "people's communes" (from the late 1950s to the late 1970s), during which the scale management of cultivated land was relatively high, the farmland in most area in China are still in the fragmented state of management. The universality of the fragmentation of cultivated land in China is the result of various factors such as natural geography, politics, economy and society. China has complex and diverse topography, vast mountainous areas, uneven distribution of agricultural land and frequent natural disasters, which results in the distinctive characteristics of natural fragmentation of the land itself; in the traditional system of equal division among sons, the household contract responsibility system with remuneration linked to output is adopted, which emphasizes equal distribution among people and combination of good and bad. Under the combined action of population growth, urbanization and the intensification of human-

Corresponding author: Jun Du
Address: [1.]Faculty of Management and Economics, Kunming University of Science and Technology, Kunming 650093, China; [2.] Department of Urban and Rural Construction and Engineering Management, Kunming University, Kunming 650214, China
e-mail ✉ dujun0605@126.com
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land conflicts, the pattern of cultivated land fragmentation in China has been further exacerbated. In order to alleviate the negative effect of land fragmentation on agricultural production and allocate land resources more effectively to stabilize agricultural development, the central government has repeatedly adjusted its land policies since 1984. Chinese government has continuously encouraged the transfer of land use rights and highly affirmed this behavior from national legislation. The No. 1 central document of 2013-2017 continued to emphasize relevant content, encouraging and supporting the moderate scale management of various forms.

Since the land transfer policy was put forward, the speed of agricultural land transfer in our country has been accelerated and the scale of land transfer has gradually increased. Whether the large-scale land transfer in rural areas can more effectively improve the efficiency of agricultural management, ensure food security and promote the development of rural society has always been argued in the academic circles. Therefore, different attitudes towards land transfer have emerged. One view is the supportive attitude towards land transfer. The small-scale peasant production may give rise to problems like land fragmentation, low land utilization rate and impediment of the application of new technologies and impediment of labor force and this view suggests that land transfer can help solve the above problems (Yuan and Lin, 2013). Land transfer can optimize the allocation of rural resources, promote the construction of modern agriculture, improve the quality of the agricultural industry, increase the income of farmers and change the lifestyle of farmers (Huang *et al*., 2011). Some scholars have pointed out that after the land transfer, the total income of the farmers has increased rather than decreased. Although the agricultural income of farmers has decreased accordingly, the proportion of non-agricultural income has gradually increased (Qian and Wang, 2016). Land circulation is beneficial for the land consolidation, which is conducive to promoting the development of China's agriculture from small-scale, part-time agriculture to the development of moderate-scale specialized agriculture. The overall agricultural comprehensive economic efficiency and land utilization can be improved in China (Xia and Kuang, 2017).

Another view argues that in the process of urbanization, the transfer of land should be prudently promoted and that China has not yet reached the point of rapid development of land transfer (He and Huang, 2011). The essence of agricultural land transfer lies in the realization of large-scale agricultural modernization of scale management. Some scholars in China have also raised objections to land transfer and believe that large-scale land use will increase land use efficiency and labor productivity and bring about scale economies effect, but reduce biodiversity and weaken the ability of crops to resist disease and pests (Liu and Jia, 2014); the application of chemical fertilizers, pesticides, machinery and modern technology will cause food safety issues and pollution of non-renewable agricultural production materials such as water, soil and air (Fu and Ye, 2017). China's No. 1Central Document in 2015 proposed that "the agricultural resources in China are scarce and over-exploited and the pollution is aggravating. How to ensure effective supply and quality security of agricultural products under the hard constraints of resources and environment and enhance the sustainable development capacity of agriculture is a major challenge that must be addressed". Meanwhile, compared with the secondary and tertiary industries, the agriculture in our country is both a basic industry and a weak industry. The contradiction of various resources in rural areas is very prominent (Zhu and Jiang, 2014). This means that the transfer of agricultural land in our country must improve the allocation and utilization of resources under the constraint of scarce agricultural resources, integrate and optimize resources and boost the effect of agricultural land transfer.

Based on the above two perspectives, this study believes that the transfer of agricultural land can break the traditional structure of agricultural resources, effectively promote the rational flow and optimization and reorganization of resource elements in agriculture and rural areas and realize effective resource integration and optimal allocation, thus manifesting and enhancing the value of resources. This is of great significance to solve the problem of fragmentation of agricultural land, increase farmers' income, agricultural development, and inefficient use and extensive management of land and is also in line with the development requirement of agricultural modernization, new rural construction and urban and rural overall development in China. However, due to the differences in the distribution of farmland resources in China, there are significant differences in the farmland transfer in different regions. At the current stage of social development, China must be cautious in advancing large-scale rural land transfer and need to make reasonable evaluation of the social, economic, environmental, and cultural impact of large-scale land transfer in different regions so as to ensure the protection of farmers' rights and interests in the land transfer process and improve the benefits of land transfer.

There are two evaluation methods that are commonly used in the evaluation of agricultural land transfer effect and they can be divided into two categories. One is the subjective evaluation method that embodies human cognition, including a multi-objective synthesis method (Zhang *et al*., 2010) and analytic hierarchy process (Cao *et al*., 2010); The other is the objective evaluation method based on mathematical models and knowledge reasoning, including fuzzy comprehensive evaluation (Jin *et al*., 2014) and factor analysis (Yang *et al*., 2010). The main problems in the application of the above methods to the evaluation of agricultural land transfer effect are as follows: subjective assessment methods have much subjectivity, lacking the quantitative expression of subjective knowledge and thus increasing the uncertainty of evaluation; the factor analysis cannot reflect the nonlinear characteristics of agricultural land systems; methods based on knowledge reasoning do not have the ability to learn nonlinearities and are too dependent on knowledge. The brain acquires sensory information, integrates cognition and controls behavioural processes. The implementation of these tasks depends on the storage and programming of information in nerve cells and their circuits and the artificial neural network constructs the intelligent bionic model that stimulates the brain's neurobehavioral characteristics, which has strong fault tolerance and adaptability. This is a powerful tool for addressing complex nonlinear problems.

The research on the effect of agricultural land transfer on resource integration effect involves many indicators and has higher requirements on the accuracy and validity of the model and the comprehensiveness and objectivity of the evaluation results. Moreover, the nonlinear problems of the system also need to be tackled. To this end, this paper establishes an evaluation index system for the scale effect of agricultural land transfer by applying the adaptive fuzzy neural network (ANFIS) rating evaluation model based on subtractive clustering and comprehensively compares the resource integration effect of agricultural land transfer effect in 31 provinces and cities in China, which provides the basis for determining the appropriate scale of land transfer.

Model Theory

Principles of Cranial Nerve and Artificial Neural Network Model

The human is a senior animal created by nature. The thinking of human beings is completed by the human brain, and thinking is the concentrated reflection of human intelligence. The cortex of the human brain contains 10 billion neurons, 60 trillion neurons and their linkers. The basic structure and functional unit of the nervous system is nerve cells, namely neurons, which consist of cell bodies, dendrites, axons and synapses. Human neurons have the following basic functional characteristics: spatial-temporal integration; dynamic polarizability of neurons; excitement and inhibition; structural plasticity; transformation of pulse and potential signals; delayed and undelayed synapses; learning, forgetting and fatigue; the neural network is a network system composed of a large number of neuron units connected to each other. The artificial neural network is the mathematical model conducting the distributed parallel information processing by imitating the behavioral characteristics of biological neural networks. This kind of network relies on the complexity of the system to achieve the purpose of information processing by adjusting the interconnected relationships among a large number of internal nodes. Artificial neural network has the ability of self-learning and self-adaptation, which can analyze the internal relationship and laws of the two by the pre-provided mutually corresponding input and output data and finally form a complex nonlinear system function through these laws. This learning analysis process is called "training." Each input connection of the neuron has a synaptic connection strength, represented by a connection weight, namely that the generated signal is amplified by the connection strength and each input corresponds to an associated weight. The processing unit quantifies the weighted input and then the sum of the weighted values is obtained through adding. After that, the output is calculated, which is the function of the sum of the weighted values. This function is generally called the transfer function.

Basic Principles of Subtractive Clustering

The subtraction clustering method is a one-time algorithm used to automatically estimate the number of clusters in the data and their positions (Chiu, 1994). In this algorithm, the candidate set of the clustering center is the sample data points and there is a simple linear relationship between the calculation amount and data points. This algorithm is also independent of the dimensions of the problem under consideration. The detailed steps of subtraction clustering analysis are as follows:

In the first step, suppose that the samples used for training are n data points (x_1, x_2, ... x_n) in M-dimensional space and each data point is a candidate clustering center.

The second step, calculate the density index D_i of data point x_i:

$$D_i = \sum_{j=1}^{n} \exp\left[-\frac{\|x_i - x_j\|^2}{(r_a/2^2)}\right] \quad (1)$$

In the above formula, the radius r_a>0, and defines a neighbourhood of the point xi. The data point with the largest density index is the first clustering center and is set as x_{c1}, whose corresponding density index is D_{c1}.

The third step is to calculate the density performance index D_i for each data point:

$$D_i = D_i - D_{c1} \cdot \exp\left[-\frac{\|x_i - x_{c1}\|^2}{(r_b/2)^2}\right] \quad (2)$$

In the above formula, r_b=kr_a (k>0, the general value is 1.5) is the proximity of the clustering center. If D_i<0, set the density index of this data point as zero and set it as the non-clustering center data point. Continue to search for clustering centers until the density index of the remaining data points is less than a certain threshold. After finding the clustering center of the data group by subtraction clustering, the number of fuzzy rules of the fuzzy system and membership functions of each input variable can be determined according to the number of clustering centers and the position of membership function on the domain can be determined.

ANFIS Principle

ANFIS is a system model that combines neural network theory and Sugeno T-S fuzzy inference system. It can build a fuzzy inference system (FIS) based on input data through the adaptive modelling method (Jang, 1993). The fuzzy rules and membership function parameters are calculated by Back-Propagation of ANN. The fuzzy rules are as follows:

Rule 1 If x_1 is A_1 and x_2 is B_1, then $f_1 = p_1x_1+q_1x_2+r_1$;
Rule 2 If x_1 is A_2 and x_2 is B_2, then $f_2 = p_2x_2+q_2x_2+r_2$;

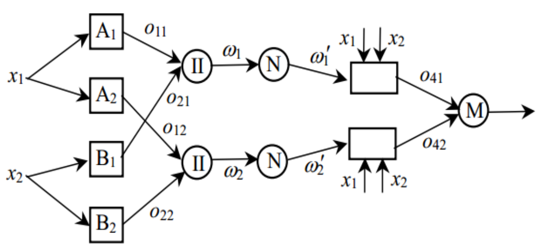

Figure 1. The structure of ANFIS

A typical two-input ANFIS is shown in Figure 1. Each node in the same layer has a similar function ($O_{1,i}$ is used to represent the output of the ith node in the first layer).

In this model, except for the input layer and the output layer, there are five layers in the middle:

(1) Input layer: each neuron in the input layer is connected to the input variable and the input variable is transferred to the next layer.

(2) The first layer is a fuzzy layer, which blurs the precise input variables in this layer and outputs the membership degree of the corresponding fuzzy set. Each node i in this layer is an adaptive node with a node function.

$$O_{1,i} = \mu_{A_i}(x_1), i = 1,2 \quad (3)$$

$$O_{1,i} = \mu_{B_{i-2}}(x_2), i = 3,4 \quad (4)$$

In the above formula, x_1 and x_2 are the input of the node and $O_{1,i}$ are the membership degree of the fuzzy set (A=A_1,A_2,B_1,B_2). If the Gaussian function is used, then:

$$\mu(x) = e^{-\frac{1}{2}\left(\frac{x_i - c_{ij}}{r_{ij}}\right)^2}, i = 1,2,..., n,\ j = 1,2,..., m \quad (5)$$

In the above formula, c_{ij} is the center of the membership function and σ_{ij} is the radius of the membership function.

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(3) The second layer is the rule-based reasoning layer. Each node in this layer is a fixed node. The output value is the algebraic product of the input value, which indicates the strength of the rule incentive, denoted as $O_{2,i}$(i=1,2), then:

$$O_{2,i} = w_i = \mu_{A_i}(x)\mu_{B_i}(x_2), i = 1,2 \quad (6)$$

(4) The third layer is the incentive intensity layer, which calculates the relative incentive strength of each rule and performs normalization processing. The nodes in this layer are still fixed nodes:

$$O_{3,i} = \overline{w_i} f_i = \frac{w_i}{w_1 + w_2}, i = 1,2 \quad (7)$$

(5) The fourth layer is the calculation output layer, which achieves the clear calculation. Each node i in this layer is an adaptive node with a node function.

$$O_{4,i} = \overline{w_i}(p_i x + q_i x_2 + r_i), i = 1,2 \quad (8)$$

In the above formula, {p_i, q_i, r_i} is the parameter set of this node, which is regarded as the conclusion parameter.

(6) The fifth layer is the assembly layer, which calculates the sum of outputs in all 4 layers.

$$O_{5,i} = \sum_i \overline{w_i} f_i = \sum_i w_i f_i / \sum_i w_i \quad (9)$$

(7) Output layer: the value of this node is passed from the fifth layer, which is used as the evaluation output result.

Analysis of Examples

Construction of Index System

The research objects in this paper are 31 provinces and cities in China and the data comes from "National Research Database" (2016). According to the principles of pertinence, directness, spatial heterogeneity, feasibility, the evaluation index system of agricultural land transfer scale effect is constructed. The evaluation system is divided into target layer, criterion layer and index layer. After the initial selection of indexes based on qualitative analysis and existing research basis, the quantitative evaluation method is used to test the evaluation index system. Two indexes, namely identification and redundancy are used to test whether there is redundancy and the redundancy level among various indexes in the evaluation system.

Asssuming that the evaluation index system includes m indexes. The index values are represented as X_1, X_2, ..., X_m respectively and there are n units to be evaluated. Then, the computational formula for the variable coefficient of index i is: $T_i=S_i/X_i$ (in this formula, S_i is the standard deviation of the ith index; X_i is the mean of the ith index). Remove the ith index of $T_i<t$ (selection criteria t=0.1). There are 9 primary indexes in the index layer in this evaluation system: C_1, mechanization rate; C_2, cultivation coefficient; C_3, effective irrigation rate; C_4, increase rate of production value; C_5, each index of land productivity; C_6, per capita disposable income; C_7, pesticide usage rate; C_8, plastic film usage rate; C_9, fertilizer usage rate. The distribution of thevariable coefficient of each index is shown in Figure 2 (index value after nondimensionalization).

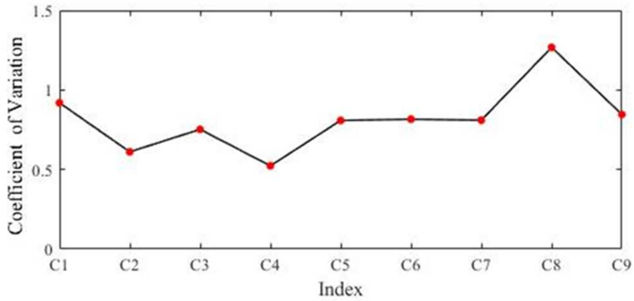

Figure 2. Coefficient of variation of evaluation index system

In order to scientifically determine the redundancy degree among indexes, the Pearson product-moment correlation coefficient is used for redundancy analysis. If the degree of correlation between two or more indexes is so high that one index can be completely linearly represented by one or more other indexes, it indicates that the index is redundant and can be deleted. The correlation coefficient is calculated in the MATLAB software and the result matrix is a symmetric matrix, namely $r_{ij}=r_{ji}$. It can be known from the calculation results that the correlation among indexes is not high. Therefore, nine primary indexes are retained and the evaluation index system is established, as is shown in Table 1.

Model Implementation

In order to ensure the nonlinear effect of ANFIS neurons, the normalization processing is conducted on the learning samples: set the sample

Table 1: Evaluation Index System for Scale Effect of Agricultural Land Transfer

Target layer	Criteria layer	Index layer	Index description
Evaluation for scale effect of agricultural land transfer A	Resource utilization degree B_1	Mechanization rate (%) C_1	Machinery usage area/agricultural land area
		Cultivation rate (%) C_2	Cultivated land area/ agricultural land area
		Effective irrigation rate (%) C_3	Real irrigation area/cultivated land area
	Land output efficiency B_2	Increase rate of production value (%) C_4	Agricultural output/ intermediate consumption
		Land productivity (%) C_5	Agricultural output/agricultural land area
		Per capita disposable income (Yuan/person) C_6	
	Ecological benefits B_3	Pesticide usage rate (ton/thousand hectare) C_7	Amount of pesticide/ agricultural land area
		Plastic film usage rate (ton/thousand hectare) C_8	Amount of plastic film/ agricultural land area
		fertilizer usage rate (ten thousand tons /thousand hectare) C_9	Amount of fertilizer/agricultural land area

data as x_i (i=1,2,...,n). According to the formula $x_i' = (x_i - x_{\min})/(x_{\max} - x_{\min})$, the sample data can be converted into the data ranging from 0 to 1.

The clustering analysis is conducted on the sample training data through the subtraction clustering method and the initial fuzzy rules of the adaptive fuzzy neural network can be obtained. Take Range of Influence=0. 9, Squash Factor=1. 25, and obtain three clustering centers of the input and output vectors, which are 3 initial fuzzy rules of ANFIS. Since there are 9 inputs and 1 output in this example andthus cannot be displayed on the spatial graph in 10 dimensions, they are projected onto the plane graph, as is shown in Figure 3. (The hollow points are sample pointsand the solid points are clustering centers)

After determining the initial rules, representative sample data in the training set is selected to train the ANFIS model. In this paper, 31 groups of samples are obtained based on the scale effect of agricultural land transfer in 31 provinces and cities in China. Among them, 21 groups are training data and 10 groups are test data. There are 9 neurons in the input layer of ANFIS model, corresponding to each evaluation index. The ANFIS model is trained through the training data and the structure and parameter of the ANFIS are optimized. It can be seen from the error convergence model that the model convergence results are good and the error does not exceed 1.6×10-6. The output curve of the training data is shown in Figure 4, and the output curve of the test data is shown in Figure 5.

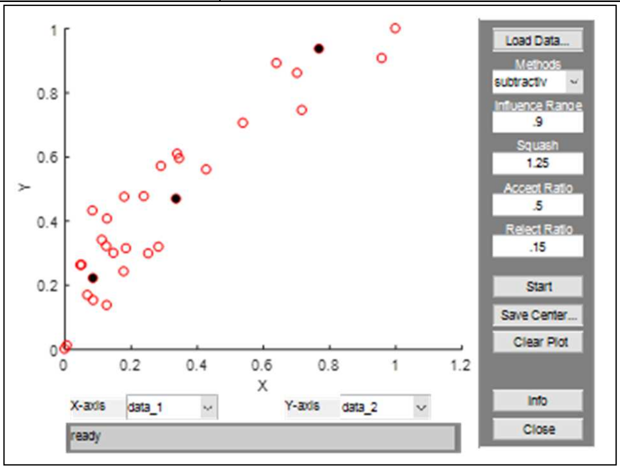

Figure 3. Sample Fuzzy Clustering

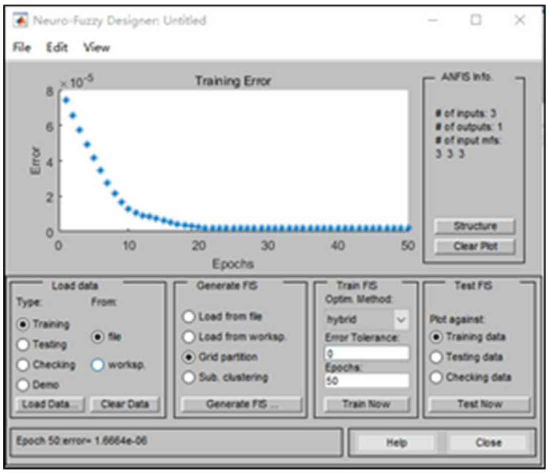

Figure 4. Convergence Curve of ANFIS System Simulation

Figure 4 shows that the training results of this model are effective and the data test can be performed using the model training parameters. In the data test, the relative error between the

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model output value and the actual value should not exceed 10%, otherwise the model will be retrained. Ten groups of index values in the test data are input into the trained ANFIS model and the evaluation results of 10 groups of test data are output. As it is shown in Figure 5 that except for a few points, the errors of most of the point are small and the average error does not exceed 6%.

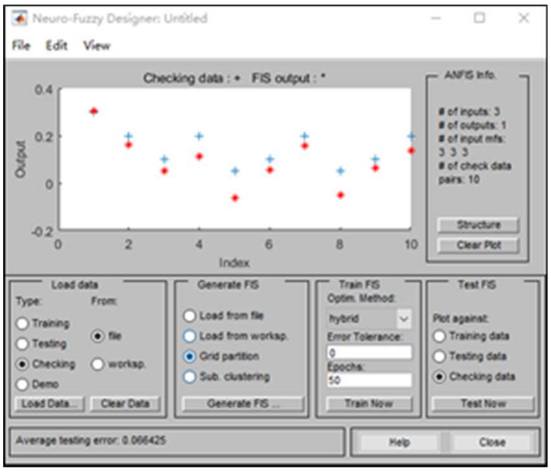

Figure 5. Error of Test Data

Summary

The subtraction clustering method is used to classify the data and find out the clustering centers, which reduces the number of samples and determines the structure of the adaptive fuzzy neural network. The adaptive fuzzy neural network selects reasonable parameters based on the known data and does not require preselection of functions. The hybrid learning algorithm (namely, combining the least square method and back propagation algorithm) is used to train the parameters, which overcomes the problems of slow convergence rate, long training time, and local minimum value and greatly saves the operation time. Based on the analysis of ANFIS model based on subtractive clustering, it is concluded that the evaluation index system of agricultural land transfer established in this paper can effectively reflect the scale effect of agricultural land transfer in China. The analysis of China's agricultural land transfer situation in China is performed according to the evaluation system and the following results are obtained:

(1) The scale effectofagricultural land transfer in China can be broadly divided into three categories: the scale effect of agricultural land transfer inHeilongjiang, Shanghai, Tianjin, Jiangsu, Zhejiang, Hubei, Guangdong, Fujian, Jiangxi, and Xinjiang is relatively good, which is classified as the first-class region; the scale effect of agricultural land transfer in in Beijing, Jilin, Shandong, Hunan, Hebei, Liaoning, Anhui, Henan, Shanxi, Ningxia and Inner Mongolia is general,which is classified as the second-class region; the scale effect of agricultural land transfer in Guangxi, Sichuan, Shaanxi, Chongqing, Tibet, Guizhou, Qinghai, and Hainan is relatively poor, which is classified as the third-class region.

(2) The utilization rate of resources in Qinghai, Yunnan and Tibet is relatively low. Because of the relatively poor geographical environment, it is difficult to introduce technology, and thus the land resources have not been effectively used; the utilization rate of machinery and cultivation rate in Shandong, Henan, and Jiangsu are relatively good, so the resource utilization rate is high.These provinces have natural advantages in scale economy. However, the higher usage rate of pesticides and fertilizers also exerts a major impact on the ecological environment.

(3) Tibet, Qinghai, Gansu and other places have a vast territory with a sparse population and the land in these regions is barren, and thus the agricultural output ratein these regions are low;the scale effect of agriculturein Hainan, Henan, Shandong and Heilongjiang is obvious.

Conclusions and Suggestions

This paper takes 31 provinces and cities of our country as the research object, adopts the combination of qualitative and quantitative analysis methods and selects 9 evaluation index systems to evaluate the scale effect of agricultural land transfer. This paper trains and tests the ANFIS model and obtains theevaluation results of different regions based on regional disparity. The results show that due to regional disparity and economic disparity, the economic effect of agricultural land transfer in different regions is not the same. Thefollowing suggestions are made according to the results of model operation:

(1) The effectiveness of land productionmodes cannot be generalized, but different production modes should be selected according to the conditions of land resources. At present, our country has a vast territory and the distribution of agricultural land is uneven. The land resources in most areas are scarce and thelabor force in rural areas is relatively abundant. It is difficult to achieve non-agricultural transfer in the short term, and we cannot simply pursue large-scale land production.

(2) Mountainous provinces like Yunan, Guizhou and Sichuan have high population density and fragile geographical environment andthe agricultural production is vulnerable to drought, waterlogging and other climatic conditions. It is difficult to form large-scale, high-standard, and unified production mode and wecannot blindly implement large-scale land transfer. However, due to defects such as fragmentation and weakness, the fragmentedsmall-scale peasant production mode is at a disadvantage in storage, processing, sales, information acquisition and technology adoption. Therefore, the government should help small-scale farmers to establish service platforms of cooperation and mutual assistance to make up the deficiencies of small peasant economy.

(3) Tibet and Qinghaihave a vast territory with a sparse populationand, on the one hand, they should improve the overall educational level and the mechanization level of agricultural productionof the region andincrease the effect of technological production; on the other hand, they can moderately transfer agricultural land and develop other industries.

(4) For first-tier cities with advanced secondary and tertiary industries such as Beijing, Shanghai, and Guangdong, they should pay more attention to the rational use of land resourcesfrom the perspective of agricultural land transfer; but if they only take the economic effect into consideration to increase the income of farmers, they should encourage the scale management and farmers to engage in non-agricultural economic activities.

(5) In view of the objective fact that China has large population and small area of land, land still plays an irreplaceable employment security function. The promotion of agricultural intensive production should implement moderate scale management based on the principle of voluntariness, compensationand conformity with legal provisions, otherwise the problem of “three rural issues” cannot be truly solved,but it may lead to more social pressure.

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