Prediction of Developing Modern Agriculture Demands for the Agricultural Scientific Research Institutions Services Based on BP Artificial Neural Network

Hongyan Sun¹, Hongwen Bi¹, Jingyuan Wang¹, Yu Zhang¹, Yanqi Wang², Zhigang Yu², Xiuli Yang², Yongshan Chai²

¹ Research Institute of Remote Sensing and Information, Heilongjiang Academy of Agricultural Sciences, 150030 Harbin, China

² Northeast Agricultural University, 150086 Harbin, China

Abstract. BP artificial neural network model is used to predict developing modern agriculture demands for the agricultural scientific research institutions services. Starting from the brief introduction of the usages of BP neural network, we analyzed the demand factors of the agricultural scientific research institutions services and the affective elements of the demands, use the BP neural network model to predict, and then run the BP neural network model on the MATLAB platform, and finally carry out the case studies of Heilongjiang Province.

1 BP Neural Network

Among many different types of artificial neural networks, the error back propagation algorithm - BP algorithm is the most widely used and popular model. BP algorithm, by definition, is calculated from backward to forward. Usually, it has a multi-layer neural network, and the BP network information flows from the input layer to the output layer. Therefore, it is a multi-layer forward neural network. The difference between BP neurons and other neurons is that the transfer function of BP neuron is non-linear, and the most commonly used function is logsig function and tansig function. Some of the output layer is linear function—purelin with the output $A = \text{logsig}(W \cdot P + b)$. After determining the BP network structure, the network can be trained with the input and output sample sets, that is to learn and correct the network thresholds and weights, so that the network can achieve a given output mapping.

1.1 The basic idea of BP algorithm

The basic idea of BP algorithm is to assign the initial network weights and threshold, and calculate forward. And then, based on the error between the achieving results and the expected results, network weights and thresholds are modified repeatedly and reversely until the minimum error is achieved. See Figure 1 and 2.

Fig. 1 Artificial neural network

Fig.2 Forward working signals and the backward error signals

1.2 Figure description

Figure 1 shows the general structure of the artificial neural networks; Figure 2 illustrates a part of the BP network, where the arrow of the concrete line is applied to the input signal that propagates forward until the

actual output at the output signal is achieved. It is the function of input and its weight. The dashed arrow is the difference between the actual network output and the expected output. It transmits backward layer by layer from the output impedance.

In 1998, Robert Hecht-Nielsen proved that any continuous function in a closed interval could be approached with a one-hidden-layer BP network, and then a three-layer BP network could complete any mapping from the n -dimension to the m -dimension. Therefore, we use a one-hidden-layer network for training.

In a three-layer BP neural network, the input vector is $X = (x_1, x_2, \dots, x_n)$ and the desired output vector is $d = (d_1, d_2, d_3, \dots, d_m)$.

The actual outputs of nodes on each level can be calculated with the forward propaganda among networks, and the input u_i of the neurons on each hidden layer is calculated as

$$u_i = \sum_{j=1}^n w_{ji} x_j - \theta_i, \quad i = 1, 2, \dots, p, \quad (1)$$

Where w_{ji} is the connection weight between the j -th neuron on the input layer and the i -th neuron on the hidden layer; θ_i is the threshold of the i -th neuron on the hidden layer. P is the neuron number on the hidden layer. The output of each neuron on the hidden layer is

$$y_i = f(u_i) = \frac{1}{1 + e^{-u_i}}, \quad i = 1, 2, \dots, p. \quad (2)$$

The input u_t and the output y_t of each neuron on the output layer are

$$u_t = \sum_{i=1}^p w_{it} x_i - \theta_t, \quad t = 1, 2, \dots, m, \text{ and} \quad (3)$$

$$y_t = f(u_t) = \frac{1}{1 + e^{-u_t}}, \quad t = 1, 2, \dots, m. \quad (4)$$

w_{it} in Formula (3) and (4) is the connection weight between the i -th neuron on the hidden layer and the t -th neuron on the output layer; θ_t is the threshold of the t -th neuron on the output layer; m is the neuron number of the output layer.

With the comparison of the expected output d_t with the actual output of the neural network y_t , the learning error which can be expressed as the mean square error e_t can be achieved as follows.

$$e_t = \frac{1}{2} \sum_{t=1}^m (d_t - y_t)^2 \quad (5)$$

2 The Main Demand Elements of the Agricultural Scientific Research Institutions Services

In the process of developing modern agriculture, the main demanding subjects for the agricultural scientific research institutions services are mainly college students,

farmers, farmers' cooperative organizations, agribusiness, and relevant government departments. The developing modern agriculture demands for the agricultural scientific research institutions services mainly include education, research and social services. There are 34 indicators in the three categories in total which include the educational needs, the research needs, and the social service needs. The educational needs include formal education, adult education, basic education and training; the research needs include the promotion of scientific research, technological innovation, etc.; and the social service needs are covered by the community, life, information services and consulting and so on.

Based on principal component analysis of the 34 indicators, and according to the principle of the over 85% accumulated variance contribution rate, the cumulative contribution rate of the three selected common factors, such as formal education, training and the promotion of the scientific and technological achievements is 89.38%, which can give a full explanation and generalization of the most data. Therefore, these three main components are selected as the indicators of the service demands because they can be a good overview of this set of data.

The calculation of the demands for the agricultural scientific research institutions services on the developing modern agriculture is mainly expressed by the sum of the formal education, training and the promotion of scientific and technological achievements. Among them, the "formal education" is represented by the product of the agriculture-related employment with a full-time agricultural college education or higher diploma and the average wages of college graduates that year; "Training" in this article specifically refers to the total revenue of the paid training offered by the agriculture colleges in the agriculture-related field; "the promotion of the scientific and technological achievements" is represented by the total technological achievement (patent) transfer of the agricultural scientific research institutions.

3 Factors of the Prediction on Developing Modern Agriculture Demands for the Agricultural Scientific Research Institutions Services

3.1 Factors of the prediction on developing modern agriculture demands for the agricultural scientific research institutions services.

There are many factors of the prediction on developing modern agriculture demands for the agricultural scientific research institutions services. Because of the complex relationships among them, we should consider the demands for the agricultural scientific research institutions services not only by the rural economic development, but also by the rural social development, and take into account the agricultural scientific research institutions input and many impact factors. The demands for the agricultural scientific research institutions

services by the rural economic development is mainly reflected in the GDP of primary industry, fixed asset investment, labor productivity and other factors. The demands for the agricultural scientific research institutions services by the rural social development exist in education, culture, family, life, and other aspects. The life indicators like the rural disposable income per capita and the consumption expenditure per capita indirectly reflect the changes in living standards and people's ability to pay for educational services.

3.2 Core of the agricultural scientific research institutions services

The core of the agricultural scientific research institutions services to the developing modern agriculture is technology. Therefore, the technological development has a close affect on demands for the agricultural scientific research institutions services. The technology development provides the prerequisite for fulfilling the functions of agricultural scientific research institutions, and opportunity to grow for the development of agricultural scientific research institutions as well. Major scientific and technological development activities are in three areas of science and technology, the scientific research expenditure, and the technical market conditions.

3.3 The five indicators with most correlative coefficients

In the factor correlation analysis of the demands for the agricultural scientific research institutions services, the five indicators with most correlative coefficients in order are the GDP of primary industry, the fixed asset investment, the rural consumption expenditure per capita, the R & D expenditure, and the agricultural university research inputs. The results of the further regression analysis are shown in Table 1.

Table 1. Indicator regression data

	Multiple R	R Square	Adjusted R Square
GDP of primary industry	0.93678	0.87639	0.83436
Fixed asset investment	0.92713	0.85386	0.81231
Rural consumption expenditure per capita	0.91955	0.83127	0.78502
R & D expenditure	0.91109	0.82304	0.77298
Agricultural scientific research institutions research inputs	0.91001	0.82297	0.77036

3.4 Table data description

Table1 shows the correlation coefficient (Multiple R) and the coefficient of determination (R Square) of the primary industry's GDP, the fixed asset investment, the

rural consumption expenditure per capita, the R & D expenditure, and the agricultural university research inputs. The adjusted R square of the Primary industry's GDP is 0.83436, indicating that this variable can explain the 83.43% of the variation for the demands for agricultural scientific research institutions services, which indicates that this variable has a good explanatory power. The fixed asset investment (0.81231), the rural consumption expenditure per capita (0.78502), the R & D expenditure (0.77298), and the agricultural scientific research institutions research inputs (0.77036) can respectively explain 81.23%, 78.50%, 77.30%, and 77.04% of the variation for the demands for agricultural scientific research institutions services, which indicates that these variable have a fine explanatory power. Based on the correlation analysis, we choose the indicators of the GDP of primary industry, the fixed asset investment, the rural consumption expenditure per capita, the R & D expenditure, and the agricultural university research inputs to predict the new rural construction demands for the agricultural scientific research institutions services. Fig.1 Caption of the Figure 1. Below the figure.

4 The Prediction of Developing Modern Agriculture Demands for the Agricultural Scientific Research Institutions Services in Heilongjiang Province

For the sake of the prediction analysis of the demands for the agricultural scientific research institutions services in Heilongjiang Province, we select the input variable of BP neural network model as the demands for services for the agricultural scientific research institutions services. When the significance level is 5%, the following relative indicators are significant: the GDP of primary industry, the fixed asset investment, the rural consumption expenditure per capita, the R & D expenditure, and the agricultural scientific research institutions research inputs. And the output variable is the amount of agricultural scientific research institutions services with the input vector $X = (x_1, x_2, \dots, x_n)$ and the desired output vector $d = (d_1, d_2, d_3, \dots, d_m)$. The termination of the learning conditions is that the global network error $E = 10^{-4}$, or that it has learned 100 times. Figure 3 shows the BP neural network structure in MATLAB.

Fig. 3 BP Neural Network Structure in MATLAB

The training process of the BP neural network is shown in Figure 3, and the training process is as follows: TRANLM, Epoch 0/100, MSE 1.38382/0.0001, Gradient 45.5102/1e-010

TRANLM, Epoch 38/100 ,
 MSE0.0731059/0.0001, Gradient 5.57148/1e-010
 TRANLM, Epoch53/100 , MSE
 0.0001879/0.0001, Gradient 0.006631/1e-010

The prediction of the demands for the agricultural scientific research institutions services by BP neural network is shown in Table 2:

Table 2 The prediction results of the demands for the agricultural scientific research institutions services in Heilongjiang Province

Year	Demand amount for agricultural college services	GDP of primary industry (100 million)	Fixed assets investment in rural areas (100 million)	Consumption expenditure per capita in rural areas (yuan)	R & D expenditure (100 million)	Agricultural labor productivity (yuan / person)	Predictive demand amount for agricultural college services (100 million)
2013	1713.65	737.6	295.6	2618.2	133.7	9160	1714.28
2014	2266.41	915.4	242.2	3117.4	199.7	11408	2267.15
2015	2282.87	1089.1	316.2	3844.7	256.5	13593	2281.32
2016	2481.32	1154.3	333	4241.3	266.6	14692	2481.97
2017	2813.98	1302.3	519.9	4391.2	299.1	15918	2813.71

Source: the data from Statistical Yearbook of Heilongjiang Province (2013-2017) and the agricultural scientific research institutions in Heilongjiang Province

5 The Analysis of the Prediction Results

To make sure of the good predictive accuracy of the BP neural network model, we use the residual test to test the results of the model. The residual calculation is shown in Table 3.

Table 3 The residual calculation

Year	K	Actual value	Predictive value	Error	Relative error
2013	1	1713.65	1714.28	0.63	0.0368%
2014	2	2266.41	2267.15	0.74	0.0327%
2015	3	2282.87	2281.32	-1.55	-0.0679%
2016	4	2481.32	2481.97	0.65	0.0262%
2017	5	2813.98	2813.71	-0.27	-0.0096%

As can be seen in Table 3, this model, with a goodness of fit, has a relatively small absolute error, indicating that the BP neural network prediction model has a very excellent accuracy; we can use this model for the scientific prediction of the total demands of developing modern agriculture demands for the agricultural scientific research institutions services. The prediction results can be calculated by the above BP neural network prediction model of the demands for agricultural scientific research institutions services as shown in Table 4.

Table 4 The total predictive value of agricultural scientific research institutions services in Heilongjiang Province, 2018-2020

Year	2018	2019	2020
Total agricultural college services	3119.62	3406.17	3920.44

To judge from the predicted results, the total demands of developing modern agriculture for the agricultural scientific research institutions services in

Heilongjiang Province from 2018 to 2020 is respectively 3119.62,3406.17, and 3920.44. The total agricultural scientific research institutions services in Heilongjiang Province grow steadily with a demand increase each year. The residual test and a posteriori error test show that the BP neural network prediction has a good accuracy.

Acknowledgement

Be funded by:Research on transformation model innovation of research findings in agricultural scientific research institutions in Heilongjiang Province(GC16D114). Science and technology innovation project of gain high yield (2018YFD0300107-6). Postdoctoral program in Heilongjiang Province (2016). Doctoral research start-up fund project in Heilongjiang Academy of Agricultural Sciences (2015).

References

1. X. Y. Guo, J. Z. Luo, *The frontier studies of the Chinese agriculture and rural economic development*. China Agriculture Press. (2017)
2. L.Q. Han, *Artificial neural network theory, design and application*. Beijing: Chemical Industry Press, pp. 3-11&27-48 (2012)
3. T. S. Lou, Y. Shi, *System analysis and design based on MATLAB- - Neural Network*. Xi'an: Xidian University Press, pp. 114-116. (2015)