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Research Article

Application Study on the Prediction of Grain Output in Huainan by Grey GM (1, 1) Model

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Abstract: In order to predict the future annual grain production in Huainan scientifically and accurately, according to the monotone increasing characteristics of the grain output in Huainan from 1995-2010, in this study, we predict the grain output from 2011 to 2014 by using the grey GM (1, 1) model and compare the prediction results with the real value, we find that the prediction has a good effect and the errors are within the scope of the permission. It is very significant for Huainan municipal government to make the corresponding economic development program, to preserve the social stability and to boost the living standards in Huainan.

Keywords: Forecast, grain yield, grey model

INTRODUCTION

Agriculture is the foundation of the national economy. Food security is not only a basic question of influencing human survival and development (Chen and Zhang, 2005), but also a major strategic issue relating to national economic development and social stability. Therefore, it is very significant for the government to make the corresponding economic development program, to preserve the social stability and to boost the living standards through scientific and accurate prediction of the future annual grain production in some area. At present, the domestic researches on grain yield prediction mainly use BP (Wang, 2002) neural network, rough set theory (Yin, 2008) and multiple linear regression (Zhou *et al*., 2011), etc. Since Grey system theory proposed by Chinese well-known scholar Professor (Deng, 1987), it has been widely used in the economic, military, transportation, environmental fields and so on, especially the grey forecasting theory which regards the research object as a changeable function with the time. When modeling, without a lot of original data, we still can obtain a more accurate prediction results which has high precision (Xie *et al*., 2013). Huainan, stretching across the Huaihe River, is located in the north-central part of Anhui Province. In the history, food production is unstable because of the suffering of the drought and flood disaster. With the development of economy and technology, as well as the state constantly increasing inputs of the water conservancy project, the food production of Huainan increased year by year and the social economy has developed rapidly in recent years. In order to predict scientifically and accurately the future annual grain production in Huainan, in this study, we predict the grain output of Huainan by using the grey GM (1, 1) model and compare the prediction results with the real value, so that we can get the corresponding conclusions.

THE GREY GM (1, 1) MODEL

The general form of the grey prediction model: Set $y^{(0)} = \{y^{(0)}(i), i = 1, 2, \ldots M\}$ as the original data of an index to be predicted, gray prediction model is established by the following steps.

Step 1: Using the formula:

$$y^{(1)}(k) = \sum_{i=1}^{k} y^{(0)}(i) = y^{(1)}(k-1) + y^{(0)}(k) \quad (1)$$

To linearly cumulatively generately process the column of data $y^{(0)}$, we get linear accumulated sequence: $y^{(1)} = \{y^{(1)}(k), k = 1, 2, \ldots M\}$, the change trend of $y^{(1)}(k)$ can be approximately described in differential equation:

$$\frac{dy^{(1)}}{dx} + py^{(1)} = q \quad (2)$$

In the Eq. (2), p and q can be obtained by the least squares method of:

$$\begin{bmatrix} p \\ q \end{bmatrix} = (B^T B)^{-1} B^T Y_M \quad (3)$$

In formula (3), Y_M is the column vector $Y_M = [y^{(0)}(2), y^{(0)}(3), \ldots y^{(0)}M]^T$, B is the constructing data matrix:

$$\begin{bmatrix} -\frac{1}{2}[y^{(1)}(1)+y^{(1)}(2)] & 1 \\ -\frac{1}{2}[y^{(1)}(2)+y^{(1)}(3)] & 1 \\ \vdots & \vdots \\ -\frac{1}{2}[y^{(1)}(M-1)+y^{(1)}(M)] & 1 \end{bmatrix}$$

Step 2: The time response function corresponding with the differential equation of (2) is:

$$y^{(1)}(x+1)=\left[y^{(0)}(1)-\frac{q}{p}\right]e^{-px}+\frac{q}{p} \quad (4)$$

And formula (4) is the basis formula of the predicted sequence.

Step 3: We can obtain the predictive value of $\hat{y}^{(1)}$ (x) of linear accumulated generating sequences by the formula of (4) and then the reduced value of the original data is:

$$y^{(0)}(k)=y^{(1)}(k)-y^{(1)}(k-1)\ (k=1,2,\cdots,M) \quad (5)$$

And the provisions of $\hat{y}^{(0)}(0)=0$.

Test of the prediction accuracy of grey forecasting model: The residual error $\varepsilon^{(0)}(k)$ and the relative error $q(k)$ between predicted values of grey GM (1, 1) model and the real value can be calculated by using the formula of:

$$\begin{cases} \varepsilon^{(0)}(k)=y^{(0)}(k)-\hat{y}^{(0)}(k) \\ q(k)=\dfrac{\varepsilon^{(0)}(k)}{y^{(0)}(k)}\times 100\% \end{cases} \quad (6)$$

In addition, we can test the prediction accuracy of formula (4) according to the following steps.

Step 1: Calculate:

$$\bar{y}^{(0)}=\frac{1}{M}\sum_{i=1}^{M}y^{(0)}(k)$$

$$s_1^2=\frac{1}{M}\sum_{i=1}^{M}[y^{(0)}(k)-\bar{y}^{(0)}]^2$$

$$\bar{\varepsilon}^{(0)}=\frac{1}{M-1}\sum_{i=2}^{M}\varepsilon^{(0)}(k)$$

$$s_2^2=\frac{1}{M-1}\sum_{i=2}^{M}[\varepsilon^{(0)}(k)-\bar{\varepsilon}^{(0)}]^2$$

Step 2: Calculate the variance ratio of $c = s_2/s_1$ and small error probability of:

Table 1: The standard of grade of grey prediction accuracy test

	Test index	
Precision grade	p	c
Good	>0.95	>0.35
Qualified	>0.80	>0.50
Barely qualified	>0.70	>0.65
Unqualified	≤0.70	≤0.65

Table 2: 1995-2014 annual grain output in Huainan city

Year	Grain output (ten thousand tons)	Year	Grain output (ten thousand tons)
1995	58.6	2005	108.0
1996	60.3	2006	127.6
1997	62.4	2007	132.4
1998	65.6	2008	134.1
1999	66.2	2009	137.0
2000	67.9	2010	139.1
2001	70.8	2011	141.6
2002	88.6	2012	133.8
2003	52.5	2013	133.9
2004	118.3	2014	139.4

$$p=\left\{\left|\varepsilon^{(0)}(k)-\bar{\varepsilon}^{(0)}\right|<0.6745s_1\right\}$$

Step 3: Compare the result of calculation of step 2 with the numerical value of the prediction precision of test table (Table 1). For p value and c value not allowed within the scope, we should analyze the residual error sequence through $\{\varepsilon^{(0)}(k)\}_{k=2}^{M}$ to modify the forecast formula of (4), the frequently-used correction methods is the residual sequence modeling method and cycle analysis method (Deng, 1987).

The scope of application of grey prediction model: From the grey GM (1, 1) model equation, we know that the calculated data from the model has its monotonicity, thus the predictive data that has been reduced back will also have its monotonicity. So the grey GM (1, 1) model has a better effect on simulation and prediction of smooth monotone data, but it is inapplicable to the simulation of non monotone data.

APPLICATION OF GREY FORECASTING MODEL IN THE PREDICTION OF FOOD PRODUCTION IN HUAINAN

Data source: We have continuously collected the annual production data for 20 years in Huainan from 1995 to 2014. The first 16 data is taken as the original data of the model, the remaining 4 data is taken as the object to compare with the prediction results of the grey model and the data is increasing monotonically, as shown in Table 2.

The solving process of the model: The original data of this study is:

Table 3: The predicted results of 2011-2014 annual grain output in Huainan city

		Grey GM (1, 1) model		
Year	Grain output (ten thousand tons)	The predicted value (ten thousand tons)	The residual error (ten thousand tons)	The relative error (%)
2011	141.6	141.3	0.3	0.2119
2012	133.8	134.7	-0.9	-0.6726
2013	133.9	136.3	-2.4	-1.7924
2014	139.4	139.8	-0.4	0.2869

$y^{(0)} = \{58.6, 60.3, 62.4, 65.6, 66.2, 67.9, 70.8, 88.6, 52.5, 118.3, 108.0, 127.6, 132.4, 134.1, 137.0, 139.1\}$

The concrete solving process using grey forecasting model is as follows.

Step 1: Using the formula (1) to obtain the linear cumulative sequence of the original data sequence $y^{(0)}$ is:

$y^{(1)} = \{58.6, 118.9, 181.3, 246.9, 313.1, 381, 451.8, 540.4, 592.9, 711.2, 819.2, 946.8, 1079.2, 1213.3, 1350.3, 1489.4\}$

$Y_{16} = \{60.3, 62.4, 65.6, 66.2, 67.9, 70.8, 88.6, 52.5, 118.3, 108.0, 127.6, 132.4, 134.1, 137.0, 139.1\}^{T}$

Constructing data matrix:

$$B = \begin{bmatrix} -\frac{1}{2}[y^{(1)}(1) + y^{(1)}(2)] & 1 \\ -\frac{1}{2}[y^{(1)}(2) + y^{(1)}(3)] & 1 \\ \vdots & \vdots \\ -\frac{1}{2}[y^{(1)}(15) + y^{(1)}(16)] & 1 \end{bmatrix}$$

There are:

$$B = \begin{bmatrix} -88.75 & -150.1 & -214.1 & -280 & -347.05 & -416.4 & -496.1 & -566.65 & -652.05 & -765.2 & -883 & -1013 & -1146.25 & -1281.8 & -1419.85 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix}^{T}$$

$$B^{T} = \begin{bmatrix} -88.75 & -150.1 & -214.1 & -280 & -347.05 & -416.4 & -496.1 & -566.65 & -652.05 & -765.2 & -883 & -1013 & -1146.25 & -1281.8 & -1419.85 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

Therefore, we can fit to get $\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} -0.071923389 \\ 48.77887541 \end{bmatrix}$ by the formula of (3).
So, the differential equation of (2) describing the change trend of $y^{(1)}(k)$ is:

$$\frac{dy^{(1)}}{dx} - 0.071923389 y^{(1)} = 48.77887541$$

The corresponding time response function is:

$$y^{(1)}(x+1) = \left[y^{(0)}(1) + \frac{48.77887541}{0.071923389} \right] e^{0.071923389x} - \frac{48.77887541}{0.071923389}$$
$$= \left[y^{(0)}(1) + 678.205982 \right] e^{0.071923389x} - 678.205982 \quad (7)$$

Formula (5) is the basis formula of food production forecasting in Huainan.

Step 2: The reduced values of the original data of food production in Huainan during 2011-2014 which is obtained by the basic formula of (5) were $y^{(0)}$ (17) = 141.3, $y^{(0)}$ (18) = 134.7, $y^{(0)}$ (19) = 136.3, $y^{(0)}$ (20) = 139.8 (Table 3).

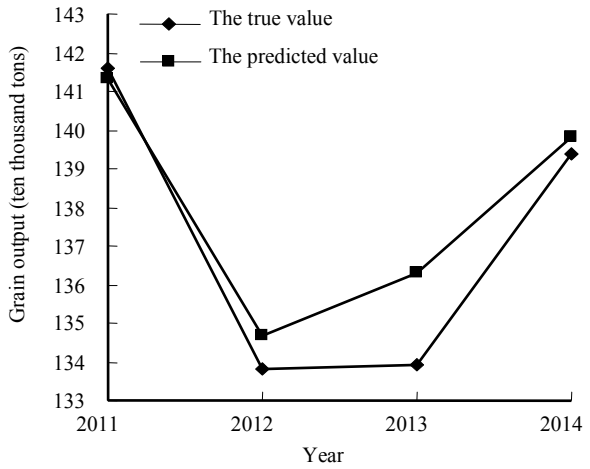

Fig. 1: The comparison chart of annual grain output predicted value with the real value during 2011-2014 in Huainan

The test of precision of forecasting numerical value: According to the inspection method of the grey prediction model which has high precision, the predicted values of annual grain output during 2011-2014 in Huainan are tested within the allowable range, so the analysis of residual sequence and the correction of the prediction formula are unnecessary (Fig. 1).

CONCLUSION

According to the monotone increasing characteristics of the annual grain output data in Huainan, the grey GM (1, 1) model is used in this study to forecast grain output from 2011 to 2014. The error is within the allowable range by comparing the results of prediction with the true value and belongs to a small probability event, the prediction has better effect. It also shows that the model to forecast the grain output in Huainan has a certain practical value.

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