Fuzzy GM(1,1) Model Based per Capital Income Predicted of Farmers in the World Natural and Cultural Heritage Area: Take Leshan City for an Example

Zhiyi Meng[1,2(✉)], Caiyang Xu[3], and Hongxing Lan[1,2]

[1] Business College,Sichuan Agricultural University,
Dujiangyan 611800, People's Republic of China
zhiyimengscu@sina.com
[2] Southwest Poverty Reduction Center,
Sichuan Agricultural University, Chengdu 610065, People's Republic of China
[3] Business College, Sichuan Agricultural University,
Dujiangyan 611800, People's Republic of China

Abstract. The per-capita income of farmer is an important technology index which is the measured level of agriculture development and the status of farmers' life. This paper aims at developing a new fuzzy grey predicting model to predict the per-capita income of farmer. The fuzzy possibility is used to check the error of the proposed model, and the test results show that the accuracy of the model is quite high, providing a scientific basis for policy makers.

Keywords: The per-capita income of farmer · Fuzzy grey prediction model · Fuzzy possibility

1 Introduction

In the past few decades, China has experienced rapid economic growth and significant reduce of poverty [3]. However, at the same time, a lot of contradictions and problems have exposed. In recent years, the problem of slow growth in farmers' income has become the focus of the society from all walks of life. The difficulties faced by the current farmers' income growth have become a big obstacle to the virtuous cycle of the whole national economy. Therefore, the study of farmers' income growth is of far-reaching significance.

Since the reform and opening, China has carried out a series of significant reform in the countryside. In 1978, the rural reform which is market-orientation is a historic turning point of the agricultural development of China: not only break the bondage of the traditional system but also promoted the growth of farmers' income greatly. From 1978 to 2008, the per capita net income of farmers increased from 134 to 4761 [1]. In particular, over the past 30 years, the changes

of the growth of farmers' income in China are as follows. With the inflation factors deducted, from 1978 to 1985, it is growing at 15.2% yearly; from 1986 to 1991, at 2.7% yearly; from 1992 to 1996, at 5.6% yearly. Besides, after 1980, 1996 is the fastest growth year of farmers living income at the rate of 9% [7]. After 1997, enter the stage of slow growth while the growth rate of farmers' income was 4.6% which was the half of 1996. In 1998, their income continued going down while the speed of growth was only 4.3%. The year of 1999 and 2000 were the same and the speed of growth was 3.8% in 1999. The farmers' income was into a trough at 2.1% in 2000. In 2001, there was a recovery growth at 4.8%. However, it reduced to 4.3% in 2003. It achieved a steady increase from 2004 to 2008 and 2008 was at 8% [6].

In conclusion, there is a large change of growth range of per farming capita income and it will cause a negative influence to the development of rural economy even the whole national economy.

As a result, the prediction of per farming capita income becomes the focus of public concern. The key of long-term agriculture development is solving the problem of agriculture, rural areas and farmers (the three agriculture-related issues) reasonably and effectively. And the problem of per capita income of farmers is not only the core of this issue but also the key to solve the problem of the three agriculture-related issues. According to the history of the economic development of China, it's clear that the per capita income of farmers has an obvious change trend. In order to solve the problem of the three agriculture-related issues better, it needs to forecast the per capita income of farmers and grasp the change trend of it accurately as much as possible. However, some uncertain factors which are in the statistical process have become the chief problem of the prediction. For per capita income of farmers, there are many kinds of uncertain factors such as quantitative and non-quantitative factor, known and unknown factor.

Neglecting those non-quantified and unknown factors, the uncertain factors affecting the per capita income of farmers can be divided into two categories: (1) The part of production grew and sold by farmers themselves; (2) The production cost of agriculture.

There are many methods for forecasting the uncertain factors. In this paper, the prediction is based on the fuzzy gray prediction model.

The gray forecasting method has been applied in the modeling process of the dynamic system successfully in different fields such as agriculture, ecology, economy, statistics, industry and environment. In the absence of long-term historical data, it can use a system model to predict the incomplete or uncertain information.

According to the statistical method of per farming capita income from the statistical yearbook, the factors affecting per farming capita income (P) mainly include: the total income of farmers (TI), the total population of agriculture (IP). The relationship between them can be expressed by the following formula: $P = \frac{TI}{IP}$.

Leshan city of Sichuan province, as an area with World double-heritages, will be used as a case to study. The problem faced by the area with World

double-heritages is how to exploit protectively. That is to say, the local natural and cultural heritages should be protected while the economy is developed and historical culture is promoted. Thus, there is a problem of degree. How to grasp this degree plays a vital role of the development of local economy and cultural protection which is also a model to the other areas with World double-heritages.

The purpose of this paper is to establish a fuzzy gray forecasting model to predict the per capita income of local farmers, get its changed trend and approve the effectiveness of the model.

2   Problem Statement

At present, per farming capita income is an important index which reflects the development of rural economy [5]. Therefore, it is very significant to predict and grasp accurately the changed trend of per farming capita income. This part will introduce the condition of per farming capita income of Leshan city and use it as an example to forecast per farming capita income with the fuzzy gray prediction model.

Due to the continuous application of the agricultural science and technology and the continuous improvement of the policies supporting agriculture by government, the total agricultural income of Leshan city has risen from 677.67 to 1992.15 million yuan in the past ten years. As shown in Fig. 1.
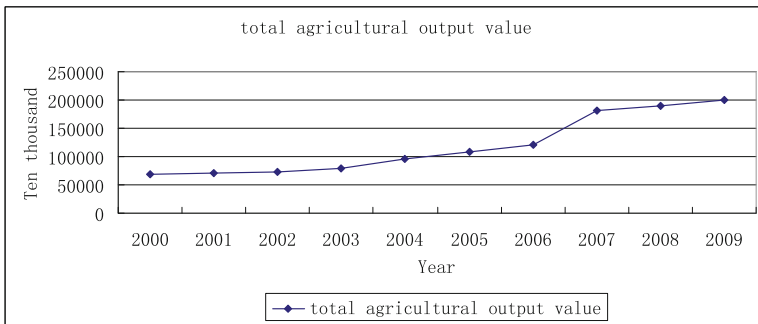
Fig. 1. The total agricultural output value of central district of Leshan city

From 2000 to 2009, the total agricultural output value of central district of Leshan city increased at a stretch. In addition to the year of 2006 and 2007, the data increased from 107.71 million yuan to 1.7 billion yuan. The overall increase in agricultural output value is in a small range and a lower growth rate. In order to a sustained and rapid growth of agricultural economy, the process of agricultural production should use advanced agricultural science and technology to increase the production and quality of agricultural products. At the same time, the policies published by government also need to be further improved.

Due to the implementation of the family control policy (a basic national policy) and the continuous improvement of the comprehensive qualities of local people, the agricultural population of central district had a tendency to reduce in Leshan city. As shown in Fig. 2.
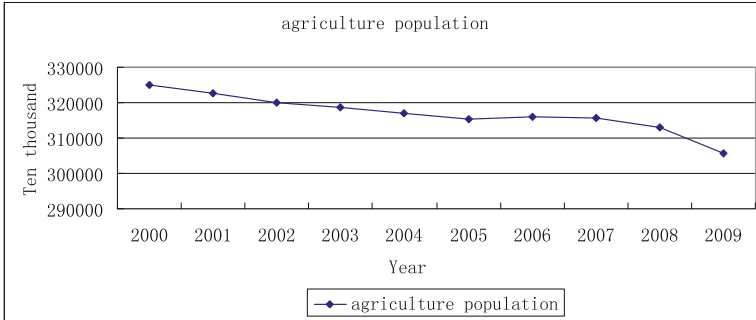
Fig. 2. The agriculture population of central district of Leshan city from 2000 to 2009

From 2000 to 2009, although there was a slight rebound from 2005 to 2007, the agricultural population of central district, Leshan city is of the gradual decline in the trend of change. The main reasons are as follows: On the one hand, affected by the Asian financial turmoil, from 2000 to 2005, crop prices were generally low and the enthusiasm of farmers was severely affected. However, since 2006, with the effect of financial crisis declining, the price of agricultural products rebounded and the enthusiasm of farmers was encouraged again. On the other hand, along with the rapid development of Chinese economy, the construction of urbanization is carried out in the vast rural areas. The acceleration of the urbanization process makes the local farming population decrease continuously. Thus, the agricultural population in central district, Leshan city also showed a decreasing trend. In summary, the total value of agricultural production of central district, Leshan city, has followed an increasing trend while the number of agricultural population has continued to decrease. Affected by the total value of agricultural production and the number of agricultural population, per capita income of farmers should also show an upward trend, as shown in Fig. 3.

From 2000 to 2009, the per capital income of farmers was increasing continuously with slow speed and low growth rate. The reasons are as follow: First, with the progress of science and technology, many kinds of advanced science and technology have been widely applied to agricultural production; second, the Chinese government has introduced various policies to support agricultural development which reduces the burden of farmers. For a sustained, rapid and steady growth of per capita income of farmers, it is necessary to improve the conversion rate of agricultural science and technology and perfect the various supporting policies of agriculture constantly.
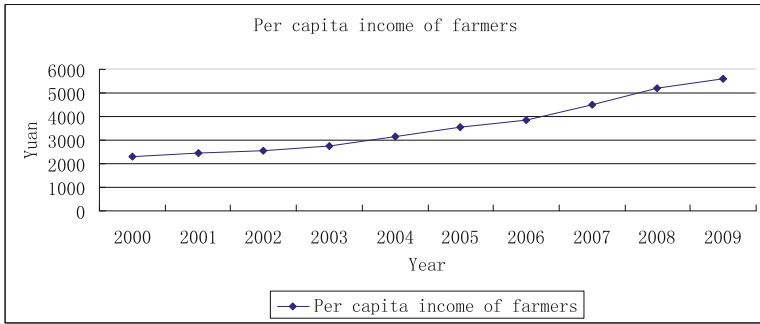
Fig. 3. The per capital income of farmers in central district, Leshan city between 2000 and 2009

3   Modeling

The gray system theory was first proposed by Deng [2], who used the differential equation as the forecasting model and the least square method to obtain the coefficient of the equation which has a wide range of application. In the gray forecasting system, the original data is defined as an accurate. However, in fact, the original data is not accurate which unable deal with the fuzzy phenomenon in reality effectively. In this paper, define the original data of per capita income of farmers as triangular fuzzy number and forecast the fuzzy numbers with gray forecasting system. Thus, this model consists of two parts: one is the fuzzy part; the other is the gray forecasting part.

3.1   Fuzzification

As mentioned earlier, the per capita income of farmers is affected by two factors: the total value of agricultural production (TI) and the agricultural population (IP). The relationship between them is: $P = \frac{TI}{IP}$.

When calculating the per capita income of farmers, this method has some shortcomings. Due to some indicators which unable get accurate enough data, it can only be estimated by experience. As a result, it will reduce the accuracy and scientificalness of the end result.

In the statistical process of the total income of farmers, some indicators unable be calculated accurately such as the part of self-production and marketing and the agricultural production cost of farmers. The self-production and marketing is the process to cost their own agricultural products. These agricultural products do not enter the market so that their value can not be measured accurately. In fact, the agricultural production cost includes labor costs while farmers own labor costs always unable be carried out. As a result, it unable be measured accurately. In these two parts of the statistical process, some indexes are often judged by experts' experience which is lack of precision.

Thus, the total income of the farmers in a region is only an estimate rather than an exact value. In this situation, it can be obscured by triangular fuzzy number to obtain a triangular fuzzy number of per capita incomes of farmers.

In order to solve the above problem, Zadeh proposed the fuzzy theory in 1965. Zadeh represent the fuzzy set by membership function following the idea that general set is represented by feature function [8].

Definition 1. Any mapping from domain X to closed interval $[0, 1]$. $\mu_A : X \to [0, 1], x \to \mu_A : (X)$. Determine a fuzzy set A of X, μ_A is called the membership function of A, $\mu_A : (X)$ is called the membership degree of X to A, fuzzy set A is written as $A = \{(x, \mu_A)|x \in X\}$.

Definition 2. Set A as a fuzzy set in domain X. If $\forall_\alpha \in [0, 1]$, the α- cut sets of A are all convex set so that the fuzzy set A is called as the convex fuzzy set.

Definition 3. If the fuzzy set M is a normal convex fuzzy set which is defined in the real field R, it is satisfied: (1) There is a unique point $x_0 \in$ R, making $\mu_M(x_0) = 1$(x_0 is called as the mean value of M); (2) $\mu_M(x)$ is continuous from left to right, then M is called as a fuzzy number. The meaning of the fuzzy number M is "the approximate real number of x_0".

From the definition of fuzzy number, the α- cut sets of M_α actually is a closed interval in real number field R: $M_\alpha = \{x \in R|\mu_M(x) \geq \alpha\} = [m_\alpha^l, m_\alpha^r]$ m_α^l and m_α^r represent severally the left and right end points of the closed interval M_α.

The general expression of the fuzzy number M is $\mu_M(x) = \{L(x), l \leq x \leq m; R(x), m \leq x \leq r\}$; and $L(x)$ is the right continuous increasing function, $R(x)$ is the left continuous decreasing function, $0 \leq L(x), R(x) \leq 1$. If both the function $L(x)$ and $R(x)$ are linear functions, M is called as triangular fuzzy number, often denoted as $M(l, m, r)$. The total income of farmers is converted to triangular fuzzy number and expressed as $M(TI^-, TI, TI^+)$. The membership function shown in Fig. 4.
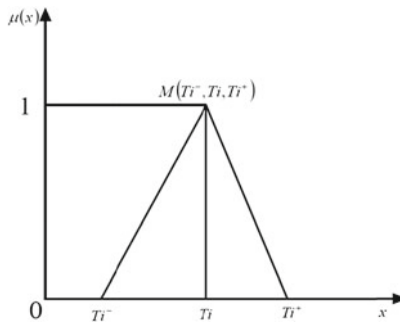
Fig. 4. The membership function of triangular fuzzy number

The relationship between the per capita income of farmers and the total income of farmers is:

$$P = \frac{TI}{TP}.$$

We can get the triangular fuzzy number of the historical data of the per capita income of farmers: $M(P^-, P, P^+)$.

3.2   GM(1.1) Model

The GM(1,1) forecasting model is described below: Regard the original data of the per capita income of farmers as a set of original data series $p^{(0)}$, we can get:

$$p^{(0)} = \{(p^{(0)^-}(1), (p^{(0)}(1), p^{(0)^+}(1)), \cdots (p^{(0)^-}(n), (p^{(0)}(n), p^{(0)^+}(n))\}$$

and

$$p^{(1)} = \{(p^{(1)^-}(1), (p^{(1)}(1), p^{(1)^+}(1)), \cdots (p^{(1)^-}(n), (p^{(1)}(n), p^{(1)^+}(n))\}.$$

The relationship between the two sequences is as follows:

$$p^{(1)^-}(i) = \sum_{m=1}^{i} p^{(0)^-}(m), i = 1, 2, 3 \cdots, n,$$

$$p^{(1)}(i) = \sum_{m=1}^{i} p^{(0)}(m), i = 1, 2, 3 \cdots, n,$$

$$p^{(1)^+}(i) = \sum_{m=1}^{i} p^{(0)^+}(m), i = 1, 2, 3 \cdots, n,$$

$$\hat{p}^{(1)}(i+1) = (p^0(1) - \frac{y}{z})e^{-ai} + \frac{y}{z}.$$

According to the least squares method, we can conclude:

$$\hat{p}^0(1) = \hat{p}^1(1).$$

Then, the final formula is obtained:

$$\hat{p}^0(i+1) = \hat{p}^1(i+1) - \hat{p}^1(i).$$

4   Application

In order to get the triangular fuzzy number of per capita income of farmers in central district, Leshan city, it's necessary to fuzzify the historical data of per capita income of farmers in this area in the past ten years. The historical data are as shown in Table 1:

Table 1. The original data of per capita income of farmers in central district, Leshan city between 2000 to 2009

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Value (Yuan)	2306	2408	2573	2748	3154	3753	3829	4497	5192	5608

We suppose that:

$$P_0(k) = (P_K^-, P_k, P_k^+),$$
$$P_k - P_k^- = \alpha,$$
$$P_k^+ - P_k = \beta.$$

According to expert experience and related theories, suppose $\alpha = \beta = 100$. According to the above method, it can get the triangular fuzzy number of per capita income of peasants in central district, Leshan city by fuzzifing the data in the above table, as shown in Table 2:

Table 2. The triangular fuzzy number of original data of per capita income of peasants in central district, Leshan city between 2000 to 2009

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
P^-	2206	2308	2473	2648	3054	3653	3729	4397	5092	5508
P	2306	2408	2573	2748	3154	3753	3829	4497	5192	5608
P^+	2406	2508	2673	2848	3254	3853	3929	4497	5292	5708

By now, input the triangular fuzzy numbers of historical data of the per capita income of farmers in the central district of Leshan city to the gray forecasting model and get the predicted values are as Tables 3 and 4 shown:

Table 3. The predicted values of per capita income of farmers in the central district of Leshan city between 2001 to 2009

| Year	2001	2002	2003	2004	2005	2006	2007	2008	2009
P^-	2260	2532	2838	3180	3563	3993	4474	5014	5619
P	2166	2435	2737	3077	3459	3888	4371	4914	5524
P^+	2354	2630	2938	3283	3667	4097	4578	5114	5714

5   Result Analysis and Suggestion

Per capita income of farmers is an important indicator to reflect the development of agricultural economy and the living conditions of farmers. Whether the

Table 4. The predicted values of per capita income of farmers in the central district of Leshan city between 2001 to 2009

Year	2010	2011	2012	2013	2014	2015
P^-	6209	6980	7847	8821	9916	11147
P	6454	7302	8262	9349	10578	11968
P^+	6384	7132	7968	8902	9945	11111
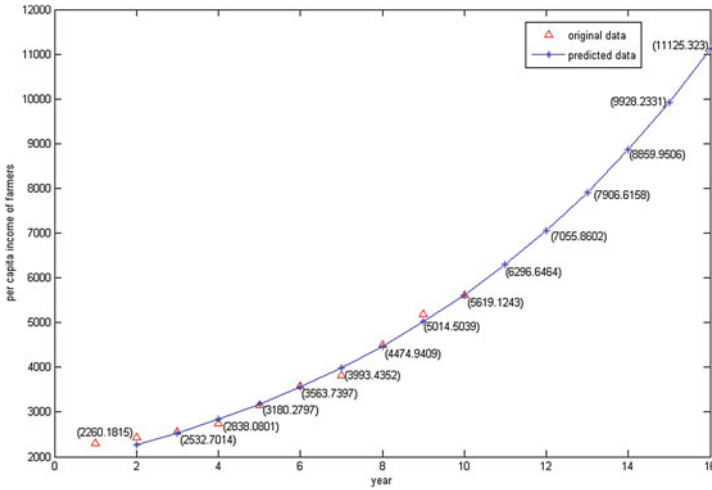
Fig. 5. The actual values and predicted values of P_K^-

per capita income of farmers has a sustained and rapid growth is important to the development of the entire national economy and the construction of a harmonious socialist society. According to the above forecast results, per capita income of farmers in central district, Leshan city is in the overall upward trend. In addition, the higher degree of fit between the predicted value and the original data indicates the validity of the fuzzy-gray forecasting model and also proves the scientificity of the predicted value. (As shown in Figs. 5, 6 and 7).

In the past decade, due to the continuous progress of agricultural science and technology and the continuous improvement of agricultural supporting policies, to a certain extent, it improved the productive rate of agriculture and reduced the burden on farmers. However, the per capita income of farmers is growing at a low speed with a low growth rate. Although there is a rising tendency, the per capita income of farmers is fluctuated because of some related economic factors.

In this view, the suggestions are as follows:

First of all, establish the work thinking of how to achieve stable increasing in income of farmers. The overall work thinking: the aim is to improve the income of farmers; the orientation is market; the support is resource; the basis is the structural adjustment; the driving force is science and technology; the way is
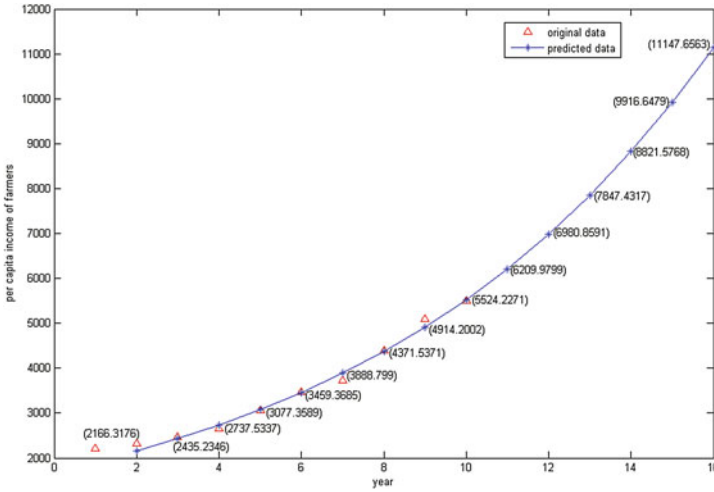
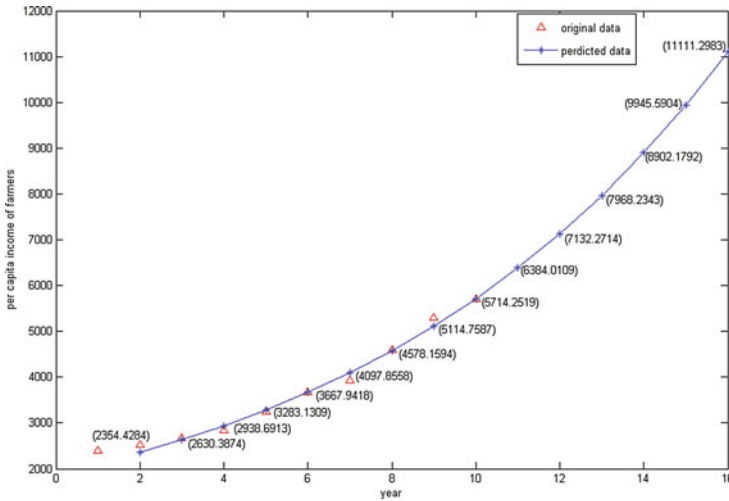**Fig. 6.** The actual values and predicted values of P_K

Fig. 7. The actual values and predicted values of P_K^+

industrialization and agricultural processing; the key is reducing agricultural population; develop green food, ecological agriculture and characteristic-brand agriculture vigorously [4].

Second, deepen the reform of the system and overcome the external factors that restrict farmers' income. China's history has proved repeatedly that when the state land and its property policy are correct and secure, when the enthusiasm of farmers is high, the income level has also a corresponding increase.

Third, the Government should implement the policy and measures to ensure that farmers' income increase. (1) It is of great significance for agricultural development and farmers' incomes to increase financial investment reasonably and carry out the agricultural subsidy policy. The funds for supporting agriculture should focus on poverty alleviation, agriculture foundational facilities, the research and application of agricultural technology and the green ecological agriculture. (2) Deepen the reform of rural financial. In the innovation of rural financial system, developing small and medium-sized banks and rural financial guaranty companies will solve the problems of rural finance fundamentally and provide a strong financial support for the development of three agriculture-related issues. It has an important role in regulation and protection to improve the production and income with the development of rural economy.

Finally, continue to promote the strategic adjustment of agricultural structure and improve the quality and efficiency of agriculture comprehensively. At this stage, improving the efficiency of agriculture should be market-oriented focusing on high quality and diversification of agricultural varieties. It means a change from yield-oriented to quality and efficiency.

6   Conclusion

Through the analysis of the per capita income of the farmers during the 30 years of reformation and opening, it is found that there are still problems in the growth process such as low growth rate and large fluctuation. Steady growth of farmers' income supports strongly for the economic with rapid growth of China and the smooth progress of reformation and opening.

In this paper, a forecasting model of the per capita income of farmers is established by fuzzy theory and gray forecasting system. As a case for our study, the central district, Leshan city provides with the relevant data. First, use the correlation theory of triangular fuzzy number to deal with the uncertain question; then use the gray forecasting model to predict the triangular fuzzy number which ensures the accuracy of the forecast results. At the same time, it provides a scientific basis for the formulation and implementation of relevant policies.

References

1. Chen LQ (2013) Discussion on growth path about per capita annual net income of rural households of guangxi farmers. J South Agric 44(8):1402–1407
2. Deng J (1990) Application of grey system theory in China. In: International Symposium on Uncertainty Modeling and Analysis, 1990, Proceedings, pp 285–291
3. Lin JY (2012) Demystifying the Chinese Economy. Cambridge University Press, New York

4. Mao M, Chirwa EC (2006) Application of grey model GM(1, 1) to vehicle fatality risk estimation. Technol Forecast Soc Change 73(5):588–605
5. Tang HJ (2008) Models and strategic countes measures for circular agriculture development in China. J Agric Sci Technol 16:28–35
6. Xiang JH, Xiao L et al (2006) The situation and evaluation of China agriculture information website development. Agric Netw Inf 2:4–7
7. Yu X, Zhao G (2009) Chinese agricultural development in 30 years: a literature review. Front Econ China 4(4):633–648
8. Zadeh LA (1965) Fuzzy sets. Inf Control 8(3):338–353