Asian Agricultural Research/亚洲农业研究 2009,1(9):29 -31 Responsible editor:Jin Yan Responsible translator:Cheng Na

Prediction of Cultivated Land Change Based on Gray Series Forecasting Model

——A Case of Puan County, Guizhou Province, China

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Abstract Both climate and cultivated land area of Puan County, Guizhou Province, China are briefly described. The six steps of Gray Series Forecasting Model are introduced, including generation of series, generation of mean value, establishment of GM (1,1) model, reducing reaction, reliability test, and extrapolation forecast. According to the data of cultivated land area in Puan County from the year 1998 to 2007, Gray System Theory is used to establish the Gray Series Forecasting Model of cultivated land area in Puan City. Since it has passed the reliability test, this model has relatively high fitting accuracy and can be used for extrapolation forecast. Based on this Gray Series Forecasting Model, extrapolation forecast of cultivated land change is conducted in Puan County from 2009 to 2012. Result shows that the expected area of cultivated land will be reduced by 1 050 hectares in the years 2009 -2012, an annual decrease of 270 hectares. And cultivated land area shows a declining trend year by year. Result of the forecasting model is close to actual value with small prediction error. Thus, it can be concluded that the result is basically credible.

Key words Gray Series Forecasting Model; Change of cultivated land area; Puan County, China

Cultivated land is the basis for food production. Balance of land supply and demand is essential for ensuring the national food security. Therefore, it is of important practical significance to predict the area of cultivated land. Domestic scholars have predicted the change of cultivated land by Gray Correlation Model. For instance, Huang Cheng-yi *et al.* have conducted scientific forecasting and simulation analysis on the dynamic change of cultivated land supply and demand in the central hilly area of Sichuan Basin in future, based on the data of cultivated land use from the year 1996 to 2004[1]. Jia Hong-jun *et al.* verify the accuracy and reliability of GM (1,1) model in cultivated land change in Wuhu City, and suggest to optimize the GM (1, 1) model[2]. However, areas researched are mostly administrative region or large natural region; and only a few researches have studied on the cultivated land change at county level. Taking Puan County, Guizhou Province, China as an example, we try to forecast the change trend of cultivated land by Gray Series Forecasting Model, so as to provide scientific basis for relevant policy making of cultivated land protection.

1 General situation of research region

Puan County is located in the southwest of Guizhou Province, having high mountains, deep valleys, steep slope, complicated geological structure, and large area of exposed carbonate rock. It belongs to subtropical monsoon climate zone, which is warm and humid. Restricted by the geological and climatic conditions, Puan County has intense Karst effects and significant rocky desertification. Under this geomorphological environment, the staggered cultivated land is mostly the slope cultivated land with shallow soil layer and poor quality. Moreover, most of the cultivated land belongs to the third and fourth classes. Reserve resources of cultivated land are mostly waste grassland and bare rock gravel. Development and utilization of agriculture needs more inputs and it is difficult to make more additional cultivated land.

Puan County has a total land area of 142.8 thousand hectares, governing 14 administrative townships. Total resident population is 311.2 thousand people in the year 2007. And cultivated land has reduced from 51.6 thousand hectares in 1998 to 48.3 thousand hectares at the end of 2007, a decrease of 3 300 hectares. At the same time, per capita cultivated land has decreased from 0.20 hectares to 0.16 hectares. Thus, it can be concluded that contradiction between supply and demand of cultivated land is serious and the man-land relationship is relatively strained.

2 Data source and research method

2.1 Data source Original data are from the 1998 -2007 *Puan Statistical Yearbook*. To make the calculation process simple and convenient, units of original cultivated land data are converted correspondingly.

2.2 Research method[3-4] Gray Series Forecasting Model is used to predict the cultivated land change of Puan County. This model is able to overcome the shortcomings of relevant data and to avoid the influence of human factors. There are six steps for series forecasting.

(1) Generation of series. $Y(t)$ is obtained by one accumulated generating operation of original series $X(t)$, in order to weaken the randomness and to strengthen its regularity.

(2) Generation of mean value. Mean generation of accumulated data $Y(t)$ is conducted. The equation is:

$$Z(t)=\frac{1}{2}[Y(t)-Y(t-1)]\ (t=2,3,\cdots,n). \qquad (1)$$

(3) Establishment of GM(1,1) model. Differential equa-

Received: September 10, 2009 Accepted: September 20, 2009

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tion of $Y(t)$ is established:

$$\frac{dY(t)}{dt}+aY(t)=u. \quad (2)$$

From equation (2), we have:

$$Y(t)=[x(1)-\frac{u}{a}]e^{-a(t-1)}+\frac{u}{a}, \quad (3)$$

where a and u are undetermined coefficients. Parameter vector is estimated according to the method of least square.

(4) Reducing reaction. According to equation (3), regressive reduction of estimate value series $\hat{Y}(t)$ is carried out. And estimate value series $\hat{X}(t)$ of original data $X(t)$ is obtained.

(5) Reliability test. We conduct fitting test on series $\hat{X}(t)$ and $X(t)$. If result of fitting accuracy is idea, the model can be applied in extrapolation forecast. But if the fitting accuracy is poor, the model should conduct residual modification before extrapolation forecast. Reliability of Gray Series Model can be tested by average relative error ($\bar{e}$), posterior error ratio (C) and small error probability (P). And then, the grade of fitting accuracy can be determined according to the grading standard of gray prediction accuracy test (Table 1).

Table 1 Grading standard of gray prediction accuracy test

Accuracy grade	P	C
Good	>0.95	<0.35
Qualified	>0.80	<0.50
Just passed	>0.70	<0.65
Unqualified	≤0.70	≥0.65

(6) Extrapolation forecast. High fitting goodness indicates a good predictive validity of model. Extrapolation forecast can be conducted:

$$\hat{X}(t)=\hat{Y}(t)-\hat{Y}(t-1) \ (t=n+1, n+2, \cdots). \quad (4)$$

3 Result and analysis

3.1 Prediction result of cultivated land area in Puan County According to the 1998 – 2007 statistical series of cultivated land area in Puan County, Gray Series Forecasting Model is established by using the above methods:

$$\hat{Y}(t)=(51.58-6\,870.319\,7)e^{-0.007\,5(t-1)}+6\,870.319\,7$$
$$=-6\,818.742\,1e^{-0.007\,5(t-1)}+6\,870.319\,7. \quad (5)$$

According to equation (5), we have the estimate value series $\hat{Y}(t)$ of $Y(t)$ and the estimate value series $\hat{X}(t)$ of $X(t)$. The result is shown in Table 2.

Based on the reliability test on series $\hat{X}$ and $X(t)$, $\bar{e}$ = 0.92%, C = 0.428 8 and P = 0.888 9 can be calculated. According to Table 1, fitting accuracy grade of Gray Series Model belongs to the grade of "Qualified". Thus, the model can be used for extrapolation forecast. Based on equation (4), Table 3 reports the predictive value of cultivated land area in Puan County from the year 2009 to 2012.

3.2 Analysis of prediction result

(1) Table 2 reports that the maximum error between predictive value and actual value is 0.92, which is 1.78% of the actual value. Actual cultivated land areas in the years 2006 and 2007 are 48.31 thousand and 48.27 thousand hectares, respectively. Prediction results in 2006 and 2007 are 48.83 thousand and 48.27 thousand hectares, and the errors are 520 hectares and 0, respectively. Thus, this prediction error is acceptable during the prediction of cultivated land change, indicating that prediction accuracy of this model is relatively high and it is of practical value.

Table 2 Comparison between series $X(t)$ and $\hat{X}$ $\times 10^3$ hm^2

Year	$\hat{Y}(t)$	$Y(t)$	$\hat{X}(t)$	$X(t)$	$\varepsilon(t)$
1998		51.58		51.58	
1999	102.26	103.18	50.68	51.60	0.92
2000	152.58	153.05	49.40	49.86	0.47
2001	202.51	202.89	49.46	49.84	0.38
2002	252.08	252.29	49.19	49.40	0.21
2003	301.27	300.99	48.98	48.70	−0.28
2004	350.10	349.52	49.11	48.52	−0.58
2005	398.57	397.85	49.05	48.33	−0.72
2006	446.68	446.16	48.83	48.31	−0.52
2007	494.43	494.43	48.27	48.27	0.00

Note: $\varepsilon(t)$ is error term.

Table 3 Predictive value of cultivated land area in Puan County $\times 10^3$ hm^2

Serial No.	Year	$\hat{X}(t)$
1	2009	47.04
2	2010	46.69
3	2011	46.35
4	2012	45.99

(2) Table 3 reports that prediction area of cultivated land in Puan County will decrease by 1 050 hectares in the years 2009 – 2012, an annual reduction of 270 hectares. Thus, reduction of cultivated land resources becomes more and more obvious. This is because that with the rapid development of economy and society and the acceleration of urbanization and industrialization, cultivated land is occupied due to the land construction, ecological restoration, disaster damage, and structural adjustment of agriculture. Although cultivated land resource is supplemented by conducting land consolidation, reclaiming waste land and exploring unused land, cultivated land quantity is still decreasing gradually. Therefore, the predictive value obtained is basically credible.

4 Conclusion and discussion

(1) Cultivated land of Puan County in the years 2009 – 2012 is predicted by using Gray Series Forecasting Model. Result shows that cultivated land of Puan County declines annually. And the result prediction model is close to the actual value with small prediction error and high prediction accuracy. Therefore, this research is of important reference value for the decision making of relevant cultivated land policy and urban development planning.

(2) The objective of this research is to find out a scientific and effective method to predict cultivated land change. Gray Model still has some deficiencies, though its prediction accuracy of cultivated land change is relatively high. Gray Forecasting

Model has obtained relatively idea prediction result of cultivated land change in short term; but it is not suitable for the long-term forecasting. Thus, prediction result would be more accurate and reliable if we comprehensively combine the Gray Series Forecasting Model with the actual factors affecting cultivated land change.

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基于灰色数列预测模型的耕地变化预测——以贵州省普安县为例

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摘要 简述了中国贵州省普安县的气候及耕地面积情况,介绍了构建灰色数列预测模型的6个步骤,即序列生成、均值生成、建立GM(1,1)模型、还原生成、可靠性检验、外推预测。根据1998~2007年普安县的耕地面积数据,运用灰色系统理论建立了普安县耕地面积灰色数列预测模型,该模型通过了可靠性检验,拟合精度较高,可进行外推预测。基于构建的灰色数列预测模型对普安县2009~2012年的耕地面积变化情况进行了外推预测。预测结果表明,2009~2012年,普安县预期耕地面积将减少1 050 hm^2,年均减少270 hm^2,耕地面积呈逐年下降的趋势;预测模型结果与实际值接近,预测误差较小,是基本可信的。
关键词 灰色数列预测模型;耕地面积;普安县

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should collect the willingness of farmers and submit a project application. After the approval of public service sector of county government, public service agency at township level needs to prepare a detailed project plan. Thus, this procedure allows rural residents to fully express their view. When operating a public service, the person who is responsible for supervision and management must be stated in management planning.

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农村公共服务问题研究及对策探讨——基于宁夏农村的调查

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摘要 市场经济条件下,市场竞争对以家庭为生产单位的农业生产者形成了前所未有的压力,农业生产者势单力薄,具有小生产特点的家庭农业生产难以有效适应市场竞争,农业生产面临着巨大的市场风险。面对市场风险,农村居民迫切需要得到多方面的公共服务。以2007年3月国家财政部和华中师范大学组织的调查活动中的宁夏地区33镇35个样本行政村1 000户农村居民的调研数据为调查资料,从公共财政建设滞后、公共卫生服务水平较低、公共文化服务发展缓慢3个方面介绍了农村公共服务供给的现状,指出我国农村公共服务的供给严重不足,难以满足农业生产、农村发展和农村居民生活的现实需要。从政府公共服务能力不足、农村公共服务供给主体单一、公共服务供给过程缺乏有效的评估机制3方面分析了农村公共服务存在的问题及原因,最后提出了通过强化各级政府的公共服务职能、构建主体多元化的供给机制、构建主体多元化的供给机制3个方面来完善农村公共服务供给的对策,以便让农村居民获得和享受必要的公共服务,发展农村经济,提高农村居民的生活水平,建立完善的社会保障体系,保证新农村建设的顺利进行和实现城乡、社会经济协调发展。
关键词 宁夏;农村居民; 农村公共服务