Research on Population Prediction of Guizhou Province

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Abstract In accordance with population development of Guizhou Province in 1977 – 2007, this paper adopts natural growth method, model prediction method and gray system GM (1, 1) model prediction method to predict population of Guizhou Province in 2020. On the basis of overall consideration of many factors of population development and future development trend of Guizhou Province, it analyzes advantages and disadvantages of three prediction methods, and obtains the prediction value of total population of Guizhou Province in 2020.
Key words Population prediction, Gray system, Guizhou Province

1 Introduction

As a core problem of researching regional land bearing capacity, population prediction is the basis of predicting various land demands, and the future population situation is important basis for determining land control indicators in the overall land use plan. There are many methods of population prediction, such as age – moving method, natural growth method, modified exponential curve, GM (1, 1) gray model, time series forecasting method and model prediction method, *etc*. Each population prediction method has its advantages and scope of application, and can predict results correctly for population development with different laws of change. Since each method has its scope of application, it is required to select appropriate method in line with characteristics of the region to be predicted, data possessed and the period of prediction, to ensure accuracy and practibility[1]. Each prediction method has its advantages and disadvantages, so it should properly apply the prediction method according to necessity of the prediction, to ensure accurate prediction.

The most distinctive characteristic of Guizhou Province is less development. Apart from historic and natural factors, population is a key factor restricting overall coordinated and sustainable social and economic development of Guizhou Province. However, there are few researches about population prediction of Guizhou Province, so it is necessary to carefully compare those prediction methods and make accurate prediction of future population of Guizhou Province. Aimed at current development situations and change characteristics of population of Guizhou Province, this study analyzes characteristics, advantages and disadvantages of prediction methods. To ensure reasonableness and accuracy of prediction, we make prediction of Guizhou Province's population in 2020 by natural growth method, model prediction method and gray system GM (1, 1). It is hoped to provide reference for relevant government

departments when formulating social and economic development plans or strategies.

2 General situations of population development in Guizhou Province

Total population of Guizhou Province rose from 26.455 million in 1977 to 39.754 million in 2007, as shown in Table 1. In these three decades, the population increased about 13.299 million with the annual growth rate up to 13.67‰. In this process, the total population takes on a gradual increasing trend, and the population growth of each year is relatively steady; the population growth rate is declining, but there is still fluctuation in some years, as shown in Fig. 1.

Table 1 Total population of Guizhou Province in 1977 – 2007 (Unit: 10^4 people)

Year	Total population	Year	Total population
1977	2 645.57	1985	3 008.75
1978	2 702.14	1986	3 026.91
1979	2 755.75	1987	3 109.11
1980	2 804.38	1988	3 164.29
1981	2 849.77	1989	3 209.67
1982	2 898.84	1990	3 258.57
1983	2 932.49	1991	3 305.67
1984	2 966.18	1992	3 352
1993	3 399.73	2001	3 798.51
1994	3 450.48	2002	3 837.28
1995	3 500.15	2003	3 869.66
1996	3 550.87	2004	3 903.7
1997	3 602.72	2005	3 931.7
1998	3 654.51	2006	3 955.3
1999	3 706.97	2007	3 975.48
2000	3 755.72		

Note: the above data is selected from the Yearbook of *Guizhou Province*.

The change trend of population in Guizhou Province since 1977: gradual increase of total population; relative slowing down of population growth in each year. In 1977 – 1989, the annual growth rate was high and the mean annual rate of growth reached 14.99‰. In 1982, the growth rate was up to 17.22‰; in 1983,

it dropped to 11.61‰. This is mainly because rural areas implement household contract responsibility system in 1982. In 1991 – 1999, the annual growth speed became slower and the mean annual rate of growth was 14.43‰. Since the entry into the new century, the total population of Guizhou Province has entered a slower growth period. In 2000 – 2007, the mean annual growth rate was 10.04‰.

3　Population prediction model

3.1　Natural growth method　In the land use planning, the natural growth model is a widely applied population prediction method. This method takes the population of prediction base period as the base number, and determines the total population of planned year period with the aid of natural growth rate and mechanical growth rate on the precondition that the population within the planned year period grows at certain annual growth rate. The common formula is as follows:

$$P_{(t)} = P_{(t_0)}(1+r)^{t-t_0} \pm \Delta P$$

where $P_{(t)}$ signifies the population of planned year period; $P_{(t_0)}$ refers to population in the prediction base period; r stands for natural growth rate of population in the prediction period; ΔP is the mechanical growth rate of population in the prediction period[2]. In this study, we take the population of 2007 as the base period population and as per the growth indicator 7.7‰ set out in the Outline of the Eleventh Five – Year Plan for Guizhou Economic and Social Development; the mechanical growth rate of population is the difference between nu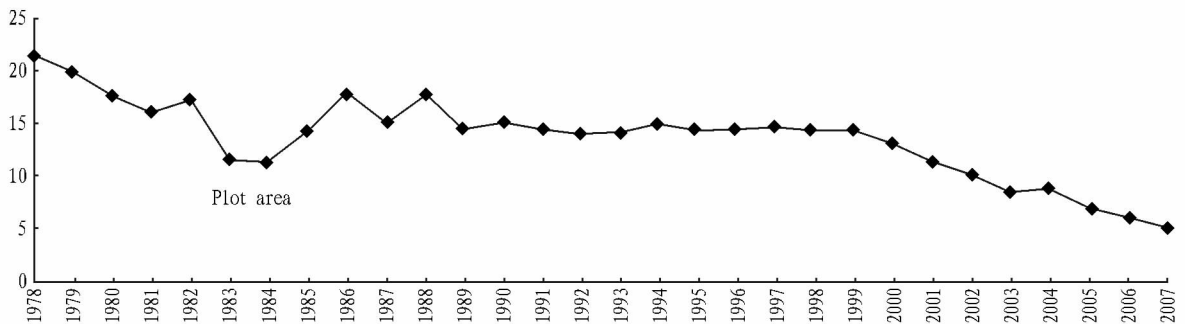mber of people moving in and out of Guizhou Province within the prediction period. Here, we adopt the average value of several years of population movement statistical data of public security department, to obtain the population of each year period. According to the natural growth model, it can get the total population of 2020 in Guizhou Province will be 43.923 million.

3.2　Unary linear regression method　In the unary linear regression method, it supposes the tangential slope of any point in the line of population development process keeps constant. In other words, the population development speed is basically consistent in each period. With the time as control variable and the population as status variable, it determines that the mathematical model between them is $y = a + bx$, where a is regression constant and the intercept of regression line; b is the regression coefficient and the slope of regression line; x is independent variable; y is dependent variable[3]. Since 1977, each year is the independent variable, and corresponding population is dependent variable, and the prediction equation is as follows:

$$y = 2\,613.63 + 46.16x \quad (R^2 = 0.997\,4)$$

This model has passed the significance test. Besides, from the comparison between the actual value and prediction value in 1977 – 2007 (as shown in Fig. 2), it can be seen that the unary linear regression prediction equation for the population of the whole province is a high accuracy fitting prediction model. According to this, it can predict the total population of Guizhou Province in 2020 is 46.446 million.

Fig. 1　Changes in annual growth rate of total population of Guizhou Province in 1977 – 2007

3.3　Gray system GM (1, 1) model prediction method　The gray system GM (1, 1) model requires little data and historical data, and does not make excessive demands on typical distribution of data. Instead, it takes proper technical processing of acquired information, and describes the dynamic process of the system at a higher level in a scientific way through establishing proper model. Compared with other prediction methods, this method has higher accuracy of prediction when there the population change is irregular, the data is incomplete, or the prediction period accounts for about 1/3 of the years with available data[4].

　　According to the population statistics of whole province in 1977 – 2007, we take all data without any screening as an independent time data series x, obtain the equidistant continuous time series value, and establish GM (1, 1) differential equation:

$$\frac{dx(t)^{(1)}}{dt} + ax(t)^{(1)} = u \quad (1)$$

Take the parameter series as $\hat{x}$,

$\hat{x} = \begin{pmatrix} a \\ u \end{pmatrix}$, get $a = -0.058\,4$, $u = 14.956\,7$

Based on the established GM (1, 1) model, $x^{(0)}(K+1) =$

$$-a\left(x^{(0)} - \frac{u}{a}\right)e^{-ak} \quad (2)$$

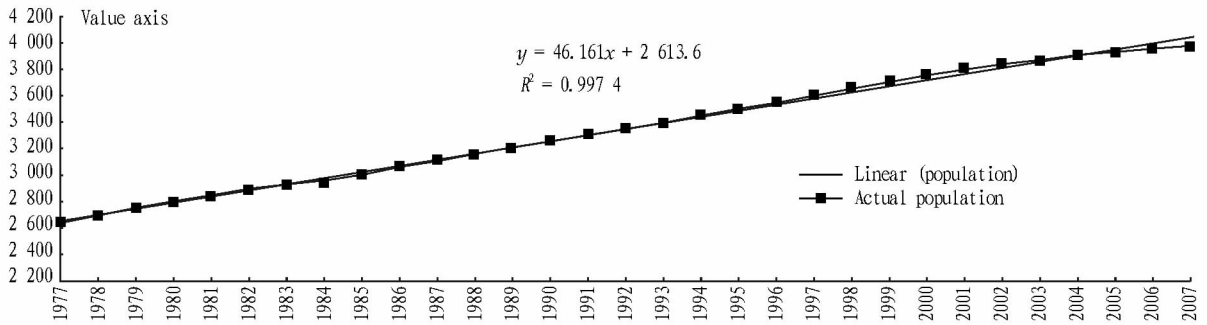Then we can get the total population of Guizhou Province in 2020 is 49.454 million.

　　The accuracy of GM (1, 1) model is mainly achieved

$$y = 46.161x + 2\ 613.6$$
$$R^2 = 0.997\ 4$$

Linear (population)
Actual population

Fig. 2   Unary linear regression model prediction

through visual judgment of residual error (θ) and MAPE. When neither θ nor MAPE exceeds 10% , the GM (1, 1) model will be deemed as high accuracy prediction model. According to residual error test, θ in the GM (1, 1) model for prediction of population of whole Guizhou Province is not higher than 8% , MAPE is 3.33% , and fitting accuracy is 96.67% . It can be seen that the GM (1, 1) model of the population of the whole province is high accuracy fitting prediction model.

3.4   Population prediction results of Guizhou Province
Since the natural growth method requires that natural growth conforms to arithmetic growth law, the prediction result is slightly low; the unary linear regression method sets constant population growth speed, the prediction result is relatively low; gray system GM (1, 1) model shows higher accuracy in the period with data available years accounting for about 1/3 , the prediction result is slightly higher.

Considering the drawbacks of the above prediction methods, characteristics of population growth in Guizhou Province, prediction results of Guizhou Province's population, the proportion of Guizhou population into the whole national population, and future development trend, we estimated the mechanical growth factor of population change and got the total population of Guizhou Province of 46 to 47.5 million.

4   Discussion
(1) Based on comparison of various population prediction methods, this study adopts unary linear regression, natural growth method and gray system GM (1, 1) to predict the total population of Guizhou Province in 2020. The population prediction results should be a proper range, rather than a value, so it can ensure

proper and accurate prediction results, and can provide a margin for future population planning. Besides, along with rapid development of economy, the population of Guizhou Province will grow at a faster speed.

(2) Population growth is influenced by many factors, so the population prediction is a complex job. The study on population prediction models has not come to a conclusion, thus the present population prediction generally combines many prediction methods. Long term population prediction is a complex and difficult matter, but medium term prediction is possible. Through analysis of historical data and selection of models, it is possible to obtain accurate prediction results. However, it should not extend the prediction results, and it is extremely difficult to ensure accuracy of prediction for several decades or hundreds of years.

(3) Mathematical model only can predict total population. For gender and age structure, it is difficult to predict. Therefore, to obtain the information about population structure, it should use special population prediction software, which is to be further tackled by software developers.

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