Study on Population Forecast Model in Planning of Land Use

ZHANG Yan-fen*, LI Ying-chao, CHEN Wei-qiang

College of Resources & Environment, Henan Agricultural University, Zhengzhou 450002, China

Abstract On the basis of describing characteristics and condition of application of natural growth model of population, weighted average growth model, regression forecast model and GM(1,1) forecast model, taking Gushi County in Henan Province as an example, according to the statistics of population in *Gushi County Statistical Yearbook* from 1991 to 2007, we establish four models to conduct fitting on population change respectively, and meanwhile, we predict population size from 2008 to 2009 and conduct preciseness test on the population size. The test results show that the preciseness of forecast results of natural growth model is not high, and the preciseness of forecast results of weighted average growth model is not scientific when the total size of population is unstable. The results of GM(1,1) forecast model and regression forecast model largely conform to the actual data, so we can take the mean of the two as the final forecast result.

Key words Planning of land use, Population forecast model, Regression forecast model, GM(1,1) gray forest model, China

Land size is an important controlling indicator in the process of overall planning of land use. In revision of land use planning, only by rational population forecast can we estimate precisely the land demand, and adjust land use structure and layout reasonably, so as to realize the optimal allocation of land resources, and guarantee the reasonability and feasibility of planning results[1]. At present, there have been multitudinous researches on forecast methods of population. Li Juan uses migration algorithm of age to consider the economic growth speed and demand of labor forces in the future and to conduct forecast research on population size of Changping in Beijing City[2]; Tan Chunying and the like apply GM(1,1) model to population forecast of Yantai City[3]; Xu Weihong and the like establish linear regression model, logistic curve model and gray GM(1, 1) model, in order to conduct forest on total population of Ningxia in the future[4]. Now that there are many models of population forecast, then how to choose appropriate model in application in order to obtain high forecast preciseness is a problem yet to be researched deeply. According to the statistics and data, this paper expounds the characteristics and condition of application in several common forecast methods of population, and takes Gushi County in Henan Province as an example in order to conduct research on how to choose and verify the forecast model of population.

1 Data source and research method

1.1 Data source Taking Gushi County of Henan Province as an example, this paper conducts research. The data are from the statistics of population in *Gushi County Statistical Yearbook* from 1991 to 2007, which can be seen in Table 1.

Table 1 The statistics of population in Gushi County from 1991 to 2007

Year	Population at the beginning of year	Population at the end of year	Average population	The births	The deaths	Mechanical growth	Natural growth rate//‰	Comprehensive growth rate//‰
1991	1 383 559	1 404 968	1 394 264	25 194	8 854	5 069	11.72	15.36
1992	1 404 968	1 422 051	1 413 510	16 252	8 711	9 542	5.33	12.09
1993	1 422 051	1 436 630	1 429 341	16 499	10 067	8 147	4.50	10.20
1994	1 436 630	1 447 970	1 442 300	16 149	9 755	4 946	4.43	7.86
1995	1 447 970	1 466 117	1 457 044	19 339	10 046	8 854	6.38	12.45
1996	1 465 117	1 482 446	1 473 782	20 863	10 375	6 841	7.12	11.76
1997	1 482 446	1 498 405	1 490 426	18 735	9 386	6 610	6.27	10.71
1998	1 498 405	1 513 667	1 506 036	19 483	9 939	5 718	6.34	10.13
1999	1 513 667	1 525 664	1 519 666	17 274	8 715	3 438	5.63	7.89
2000	1 525 664	1 522 492	1 524 078	17 983	9 447	-11 708	5.60	-2.08
2001	1 522 492	1 541 069	1 531 781	16 318	8 533	10 792	5.08	12.13
2002	1 541 069	1 552 207	1 546 638	13 852	8 692	5 978	3.34	7.20
2003	1 552 207	1 560 454	1 556 331	14 483	8 481	2 245	3.86	5.30
2004	1 560 454	1 591 102	1 575 778	12 825	7 707	25 530	3.25	19.45
2005	1 591 102	1 592 102	1 591 602	13 102	7 832	-4 270	3.31	0.63
2006	1 592 102	1 618 418	1 605 260	13 348	7 156	20 124	3.86	16.39
2007	1 618 418	1 656 145	1 637 282	18 255	7 352	26 824	6.66	23.04

Note: Data are from *Gushi County Statistical Yearbook*.

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* Corresponding author. E-mail: yanfen424@163.com

1.2 Models of population forecast

1.2.1 Natural growth model of population. Prerequisite of

using this model is as follows: the population amount in the planning region basically increases at certain proportion, and we assume that the population in this region increases in the future still at this average growth rate, and the mechanical growth amount is easily determined[5].

The formula is as follows:

$P_{(t)} = P_{(t_0)} \times (1+r)^{(t-t_0)} + Q_{(t)}$

In the above formula, $P_{(t)}$ is the population amount in planning year; $P_{(t_0)}$ is the population amount in base year; r is the natural population growth rate (‰); $Q_{(t)}$ is the mechanical growth amount.

1.2.2 Weighted average growth model. Generally, one region at different stages of economic development has different natural growth rate of population. In this case, we should use the weighted average growth model to conduct calculation[6]. We can use the following formula to conduct calculation:

$$P = P_0 \times (1+R)^a$$

$$R = \frac{\sum_{i=1}^{n} W_i R_i}{\sum_{i=1}^{n} W_i};\ R_i = \sqrt[t_i - t_{oi}]{\frac{P_i}{P_{oi}}} - 1;$$

$$W_i = \frac{1}{\sum_{i=1}^{n} \frac{1}{T - \left[\frac{t_i + t_{oi}}{2}\right]}} \times \frac{1}{T - \left[\frac{t_i + t_{oi}}{2}\right]}$$

In the above formula, P is the population amount in the planning target year; P_0 is the population amount in the planning base year; R is the average population growth rate during the planning period; a is planning year; W_i is the weights of data set;; R_i is the average growth data set rate; P_i is the number of population of data set in end year; P_{oi} is the population amount of data set in starting year; t_i is the year when the i^{th} data set ends; t_{oi} is the year when the i^{th} data set begins; T is base year; n is the amount of data set.

1.2.3 Regression forecast model. According to the mutual relationship among variables, the regression forecast model uses the known value of other variables to extrapolate the value of prediction variables. By establishing the mathematical relationship between time sequence and population, we forecast the population in the future[7] as follows:

$\hat{Y} = a + bX$

In the above formula, $\hat{Y}$ is the prediction value of population size; X is sequence; a, b are regression coefficient.

1.2.4 GM(1,1) gray system model. Gray system adopts the method of using cumulative summation (cumulative subtraction) to generate number to transform obviously irregular data sequences, to get the regular sequences, so that we can use curve to conduct approximation, and conduct reasonable forecast on future data[8]. The steps of establishing GM (1, 1) grey model[9] are as follows:

First, conduct cumulative summation on the original series $x_{(k)}^{(0)}$ so as to generate $x_{(k)}^{(1)}$, and conduct cumulative summation on the original series $x_{(k)}^{(1)}$ so as to generate consecutive mean $z_{(k)}^{(1)}$.

Second, construct first order linear differential equation as follows:

$\frac{dx_{(k)}^{(1)}}{d_t} + ax_{(k)}^{(1)} = \mu$, where $\begin{bmatrix} a \\ \mu \end{bmatrix} = (B^T B)^{-1} B^T Y_N$.

Third, construct accumulation matrix $B = \begin{bmatrix} z_{(2)}^{(1)} & 1 \\ z_{(3)}^{(1)} & 1 \\ \vdots & \vdots \\ z_{(n)}^{(1)} & 1 \end{bmatrix}$, constant term vector $Y_N = \begin{bmatrix} x_{(2)}^{(0)} \\ x_{(3)}^{(0)} \\ \vdots \\ x_{(n)}^{(0)} \end{bmatrix}$, and use least square method to calculate grey parameter a and μ.

Fourth, put grey parameter into time function, and get forecast model as follows:

$$\hat{x}_{(k+1)}^{(1)} = \left[x_{(1)}^{(0)} - \frac{\mu}{a}\right] e^{-ak} + \frac{\mu}{a};$$

Fifth, establish forecast recovery model as follows:

$\hat{x}_{(k+1)}^{(0)} = \hat{x}_{(k+1)}^{(1)} - \hat{x}_{(k)}^{(1)}$.

1.3 Evaluation method of quality of forecast model By comparing the relative errors between prediction value and actual value, and standard deviations of relative error, we evaluate the quality of the four models[10], and the formula is as follows:

$$e_i = [x_{(i)} - y_{(i)}] / x_{(1)};\ S = \sqrt{\frac{1}{n}\sum (e_{(i)} - \hat{e}_{(i)})^2}$$ [11]

In the above formula, $e_{(i)}$ is relative error; S is the standard deviation of relative error; $x_{(1)}$ is original sequence; $y_{(i)}$ is forecast series of numbers.

2 Results and analysis

2.1 Determination of model coefficient

2.1.1 Natural growth model. According to data from *Gushi County Statistical Yearbook* and birth indicator of population provided by family planning departments in Gushi County, coupled with the national economic statistics, and the natural population growth trend from 1991 to 2007 in Gushi County, we determine the natural population growth rate in planning period as 4.90‰, the average mechanical growth rate as 8,100 people/year.

2.1.2 Weighted average growth model. By analyzing the population data from 1991 to 2007, and considering the relationship between population growth and time, we divide the data broadly into three time groups: from 1991 to 1997, from 1998 to 2002 and from 2003 to 2007. Based on the above data groups, we determine the average growth rate of each group as 11.18‰, 7.43‰, and 11.46‰ respectively; determine the weight as follows: $P_1 = 40/63$, $P_2 = 13/58$, $P_3 = 11/78$; ultimately determine the average growth rate of population $R = 10.38‰$.

2.1.3 Regression forecast model. According to basic data of Gushi County, population is as dependent variable Y, and sequence number of year is as independent variable X (1 in 1991, 2 in 1992, and the rest can be done in the same manner). After linear regression analysis, we get simple regression model: $y = 1\,386\,981.60 + 13\,832.89x$; $R^2 = 0.99$; F test value = 1.009×10^{-16}. It shows that the time series and population size has obvious linear relationship.

2.1.4 GM(1,1) gray system model. By a series of calculation of accumulation or gradual subtraction on the original time se-

ries from 1991 to 2007, we get gray parameter as follows: $a = -0.009$, $\mu = 1\ 399\ 480.336$. We conduct consistency test on the model, and the absolute value of the relative error of model is no more than 2%, thus we can think that the fitting accuracy of this model is high.

2.2 Test of model preciseness

2.2.1 Test of model on fitted preciseness of original data. We use the 4 population calculation models we have established to calculate the population from 1991 to 2007 respectively, and conduct comparative analysis on actual size of the population and calculation value. By comparing the standard deviation of relative error and relative error (Table 2), we test and verify the accuracy of forecast results of all models[12]. We can see from the data in Table 2 that the mean of the relative errors and standard deviation of relative errors of forecast results of gray system model are both minimal, indicating that the forecast results of gray system model is most accurate, followed by the regression model. The model with poorest performance is the natural growth model and the weighted average growth model.

Table 2 Test value of all models on preciseness of original data

Test of model	Natural growth model	Weighted average growth model	Regression model	GM(1,1) model
Relative error//%	−0.22	−0.29	0.01	0
Standard deviation of relative error//%	0.62	0.74	0.41	0.41

2.2.2 Test of fitted preciseness of data extrapolated by model. We conduct extrapolated verification and test on the forecast model of population we establish, and we use the above four models to predict population in 2008 and 2009 respectively, and compare them with the actual population amount[13], so as to analyze the prediction accuracy of all models, which can be seen in Table 3. By the comparative analysis, the forecast accuracy from high to low is as follows: regression model, GM (1,1) model, natural growth model and weighted average growth model.

Table 3 Forecast error of extrapolated data of all models

Year	Actual statistic People	Natural growth model		Weighted average growth model		Regression model		GM(1,1) model	
		Forecast value People	Relative error %	Forecast value People	Relative error %	Forecast value People	Relative error %	Forecast value People	Relative error %
2008	1 625 990	1 652 772	1.65	1 661 826	2.20	1 635 974	0.61	1 638 090	0.74
2009	1 599 971	1 668 296	4.27	1 679 076	4.94	1 649 806	3.11	1 652 899	3.31
Mean	1 612 981	1 660 534	2.96	1 670 451	3.57	1 642 890	1.86	1 645 495	2.03

2.3 Results and analysis of reason First, the core content of natural growth method is to determine the average natural growth rate of population and mechanical growth amount of population. This method used in this paper is that we assume that the population in the regions grows at the fixed population growth rate, and the mechanical population growth amount annually is the same. We can see from the data in paper from 1991 to 2007 that the fluctuation of mechanical growth of population is great, leading to the unstable comprehensive growth rate of population, so directly using average natural growth rate and mechanical growth to predict the future results will have not high accuracy.

Second, although the weighted average method considers the correlation between time and growth rate, conducting smooth observation by time sequence can avoid the results of prediction value lagging behind observation value, and promote observation accuracy. We should also consider the actual situation. In this case, when the total size of population varies and becomes unstable, the representativeness of the population growth rate close to the base year is not high, and blindly assigning weight is unscientific.

Third, regression forecast method can be applied to prediction when the linear trend is prominent. Under the circumstance that the original series of number is long and the growth trend is stable, the goodness of fit of regression forecast model is good.

Fourth, GM (1,1) forecast model can effectively weaken the randomness extent of the original data, and increase the stability of data. In addition, the data amount required for the model is small, so usually we can establish model by four data. When the fluctuation of historical data of regional population is great, we cannot conduct regression by linearity or simple curve, or when the data is incomplete, GM (1,1) model can effectively replace other models to predict.

3 Conclusion

In reality, all kinds of forecast models of population have certain advantages and limitations, so we should choose the forecast model according to the characteristics of problem in itself. In the case of this paper, as the original series of numbers are too long, so it highlights the advantages of the regression model; but there are several fluctuations among data, so the fitted preciseness of GM (1,1) model is high, and using the mean of the two as the final forecast result is more scientific. When conducting forecast of population, we suggest that we should conduct the comparative test and verification of many kinds of models, compare the advantage and disadvantage of all models, and determine the most ideal model through qualitative and quantitative analysis.

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these need further study in the following testing areas and educational circles. The writer holds that the following should be achieved for the organic integration of China's minimum subsistence security system and poverty alleviation policies. Firstly, management departments should be organically coordinated in capital and operation. Secondly, objects should be recognized separately and their convergence is not omnipotent. Thirdly, the maximization effect of capital should be the precondition of the implement of poverty alleviation and minimum subsistence security system. Lastly, the bottom line is that national support in capital and policy should be sustainable.

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