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Grain Yield Prediction of Henan Province Based on Spatio-temporal Regression Model

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Abstract By using correlation analysis method, regression analysis method and time sequence method, we combine time and space, to establish grain yield spatio-temporal regression prediction model of Henan Province and all prefecture-level cities. At first, we use the grain yield in prefecture-level cities of Henan in the year 2000 and 2005, to establish regression model, and then taking the grain yield in one year as independent variable, we predict the grain yield in the fifth year afterwards. Taking the dependent variable value as independent variable again, we predict the grain yield at an interval of the same years, and based on this, predict year by year forward until the year we need. The research shows that the grain yield of Henan Province in the year 2015 and 2020 is 59.849 6 and 67.929 3 million t respectively, consistent with the research results of other scholars to some extent.

Key words Spatio-temporal regression model, Moving prediction year by year, Grain yield, Henan Province, China

Henan Province is the first major grain-producing province in China. The grain yield of Henan Province accounts for 10 percent of total yield in China. It not only solves the problem of feeding in the first most populated province, but also each year supplies 10 billion kilograms of grain to help other provinces, making great contribution to national food security[1]. But with the rapid increase in population in Henan and the reduction of arable land, grain production pressure in Henan Province becomes increasingly big. The development trend of grain production in Henan Province exerts great influence on food security in Henan Province and China. Therefore, the scientific predictions of future grain yield in Henan Province, are of great significance to macroeconomic decision-making in China.

Many scholars use different research methods, to conduct many arduous studies on the grain yield prediction in Henan Province. For example, Guo Liying *etc.* use multiple regression method, and focus on influencing factors of grain production, to establish multiple regression equation, and predict the grain yield[1]; Libing Jun *etc.* use gray linear regression model to conduct short-term prediction on the future grain production of Henan Province[2]; Li Jinxia, He Zhen *etc.* use gray theory to conduct medium-and-long-term prediction on the grain production in Henan Province[3-4]. However, these predictions are the predictions on the grain yield of Henan Province from the perspective of time sequence, never reflecting the spatial changes of grain yield in Henan Province. We design a simple spatio-temporal regression prediction model, to conduct prediction on the grain yield of Henan Province and the municipalities, and in the mean time, conduct coordination and arrangement for the related government departments, and provide scientific reference basis for formulating appropriate countermeasures.

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1 The principle and steps of establishing spatio-temporal regression prediction model

1.1 The principle of establishing model The spatio-temporal regression prediction model designed by us is to use time data and spatial data, convert the independent variable and dependent variable alternately, and conduct prediction moving forward. It comprehensively uses correlation analysis, regression analysis and time series analysis method, and combines time and space together to establish spatio-temporal regression prediction model, in order to conduct asynchronous prediction on grain development, that is, to use one reason or condition of something in different regions today to predict certain results in these regions tomorrow or day after tomorrow. Using regression analysis and time sequence analysis method to conduct prediction can be considered as synchronous prediction, that is, using regression analysis and time sequence analysis method to predict certain results caused by certain factors or certain time, is synchronous in terms of time. The spatio-temporal regression model not only has the thought of time sequence method, that is, the conditions in all regions today will continue stably, but also is the method of causal analysis, that is, the results tomorrow or the day after tomorrow happen on the basis of today. For grain yield prediction, it is to use the spatio-temporal data matrix X of grain yield in different regions a few years ago to establish regression equation, then take the grain yield in all regions in a particular year as independent variable, to predict unknown grain yield of all regions in a year afterwards. The regression equation of predicting grain yield in different regions and different time is called as grain spatio-temporal regression model.

1.2 Specific steps The prediction steps are as follows. Establish data matrix: select the grain yield data in all regions in recent years, to get the following matrix, where column is year,

namely time data; line is region, namely spatial data.

$$X=\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

Use matrix (1), to conduct correlation analysis on all columns of data, to get the correlation coefficient matrix as follows: $R=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix}$ (2)

Test all correlation coefficients. If passing test, then according to data matrix (1), we use two-year data (the adjacent two years or every a year or many years) to establish spatio-temporal regression equation (generally not including regression constant) as follows:

$$\begin{bmatrix} y_1(t+i) \\ y_2(t+i) \\ \cdots \\ y_m(t+i) \end{bmatrix}=b\begin{bmatrix} x_1(t) \\ x_2(t) \\ \cdots \\ x_{1m}(t) \end{bmatrix}, \text{or written as: } Y=bX \quad (3)$$

In expression (3), y is the prediction value of future grain yield (dependent variable) in one certain region; x is the actual value of grain yield (independent variables) in the region in the past; m is m spatial regions ($m=1,2,3,4,5,\cdots$), the selected sample capacity; t is one certain year; i is the interval of years between two years ($i=0,1,2,3,\cdots$); b is spatio-temporal regression coefficient. By using equation (3), and selecting data in one year in all regions as independent variables, we conduct prediction on the grain yield in the same interval of years.

When conducting grain yield prediction, we can use last year and this year's actual value of grain yield in all regions to establish spatio-temporal regression equation, and then substitute the actual value of grain yield in all regions this year in equation, to predict the grain yield next year. Then we use the prediction value next year as independent variable, to predict the grain yield the year after next. In a similar manner, by alternating the independent variables and the dependent variable, we predict year by year forward until the year we need. Similarly, we can use the data the year before last and this year, with an interval of one year, to establish spatio-temporal regression equation, and then use the data last year to predict grain yield the year after next. Or we can use the data with an interval of several years to establish spatio-temporal regression equation, and use the data in one year to predict the grain yield another year with the same interval of years.

2 The application of spatio-temporal regression prediction model in prediction of grain yield in Henan Province

2.1 Correlation analysis Usually, before the establishment of spatio-temporal regression model, we should conduct correlation analysis. If the data correlation in all regions in all years is not obvious, then the prediction error of the results is big, thus establishing spatio-temporal model is largely meaningless. Although grain production is in fluctuation, on the whole, there is correlation between the years, because the grain yield in one region in the coming years is carried on based on the yield of the previous years. We select 9 years of grain yield data in Henan Province from 2000 to 2008 to conduct correlation analysis[5], and the results show that the correlation of grain yield in prefecture-level cities in all years is very significant (Table 1), so we can use alternately moving spatio-temporal regression prediction method.

Table 1 The correlation coefficient of grain yield in prefecture-level cities of Henan Province from 2000 to 2008 (significance level is 0.01)

	2000	2001	2002	2003	2004	2005	2006	2007	2008
2000	1.000	0.960	0.947	0.948	0.947	0.938	0.940	0.940	0.947
2001	0.960	1.000	0.966	0.995	0.995	0.995	1.000	0.990	0.991
2002	0.947	0.966	1.000	0.968	0.971	0.963	0.970	0.960	0.969
2003	0.948	0.995	0.968	1.000	0.999	0.998	1.000	1.000	0.988
2004	0.947	0.995	0.971	0.999	1.000	0.999	1.000	1.000	0.993
2005	0.938	0.995	0.963	0.998	0.999	1.000	1.000	1.000	0.993
2006	0.944	0.995	0.968	0.995	0.998	0.998	1.000	1.000	0.998
2007	0.938	0.994	0.964	0.995	0.997	0.999	1.000	1.000	0.997
2008	0.947	0.991	0.969	0.988	0.993	0.993	1.000	1.000	1.000

2.2 Establishment of spatio-temporal regression model When establishing spatio-temporal regression model of grain yield prediction in Henan Province, by using the data in the year 2000 and the year 2005, with an interval of 4 years, we establish spatio-temporal regression equation, and then use the data in the year 2001 to predict grain yield in the year 2006 or use the data in the year 2002 to predict grain yield in the year 2007, and so forth. The spatio-temporal regression model we establish by using the year 2000 and the year 2005 is as follows:

$$Y_{2005}=1.135X_{2000} \quad (4)$$

How is the effect of spatio-temporal regression model that we establish? Is it strong to reveal spatio-temporal law? How is the accuracy of prediction when using it? All these questions require us to conduct significance test. If it is significant after passing test, it indicates that the regression model we establish is effective, otherwise, it would be meaningless. By variance analysis (Table 2), we know that the significance probability of hypothesis test is 0.000, far less than significance level of 0.01. It shows that the relationship between Y and X is very close, and the regression equation is effective.

2.3 The future prediction of grain yield in Henan Province By using regression equation (4), we use the grain yield in the

year 2004, at an interval of 4 years, to predict the grain yield in the year 2009, use the grain yield in the year 2005 to predict the grain yield in the year 2010, until the year 2020. The prediction results are seen in Table 3.

After adding the grain yield of prefecture-level cities, we get the gain yield of whole province. The result is that in the year 2015 the total grain yield of whole province is 59.849 6 million tons and in the year 2020 the total grain yield of whole province is 67. 929 3 million tons (Table 3). There is certain similarity after comparing this result with researches of Libing Jun[2], Li Jinxia[3] and He Zhen[4] (Table 4).

Table 2 Variance analysis of spatio-temporal regression model

Variation	Degree of freedom	Quadratic sum	Mean square	*F* statistic	Significance
Regression analysis	1	1 643 904	1 643 904	1 190.812	1.89E-16
Residual	17	23 468.33	1 380.49		
Total	18	1 667 372			

Table 3 The grain yield prediction in prefecture-level cities of Henan Province $\times 10^4$ t

Prefecture-level city	Year					
	2009	2010	2011	2012	2015	2020
Zhengzhou City	168.32	173.66	187.16	186.59	197.10	223.71
Kaifeng City	219.40	230.63	265.36	271.27	261.77	297.11
Luoyang City	236.08	238.92	260.37	259.80	271.17	307.78
Pingdingshan City	183.19	183.08	207.02	214.97	207.79	235.84
Anyang City	278.64	287.84	335.51	363.43	326.69	370.80
Hebi City	100.90	105.44	114.41	121.45	119.68	135.83
Xinxiang City	335.39	353.55	394.87	416.32	401.28	455.46
Jiaozuo City	183.19	188.52	205.55	218.83	213.97	242.86
Puyang City	223.14	229.72	256.28	270.92	260.74	295.94
Xuchang City	260.03	263.66	292.04	300.89	299.25	339.65
Luohe City	149.93	150.73	177.63	177.63	171.08	194.17
Sanmenxia City	53.57	55.96	68.55	60.38	63.51	72.08
Nanyang City	514.38	528.80	598.37	624.70	600.18	681.21
Shangqiu City	515.18	549.91	618.23	647.18	624.15	708.40
Xinyang City	450.60	481.69	578.96	603.25	546.72	620.53
Zhoukou City	614.26	626.86	731.85	777.59	711.49	807.54
Zhumadian City	612.56	603.25	706.88	688.72	684.69	777.12
Jiyuan City	20.32	20.88	24.06	23.61	23.70	26.90
Total	5 119.08	5 273.10	6 023.10	6 227.52	5 984.96	6 792.93

Table 4 Grain yield prediction value of Henan Province and the comparison with other related researches $\times 10^4$ t

Researcher	2009	2010	2015	2020
Li Bingjun *etc.*[2]	5 681.8	5 977.6		
Li Jinxia *etc.*[3]	5 075.9	5 198.8	5 859.5	6 604.2
Hezhen *etc.*[4]	5 122.6	5 261.6	6 015.1	6 876.4
Liu Qinpu	5 119.1	5 273.1	5 985.0	6 792.9

Thus, the spatio-temporal regression model we propose is available. Compared with other models, the advantage of this method is as follows: it just collects short-term grain yield data, and uses simple unitary regression analysis method; a model solves grain prediction problems of many prefecture-level cities. In addition, the data of Henan Province are obtained on the basis of grain yield prediction in all prefecture-level cities. Some of the errors offset each other, and prediction results are more accurate and convincing.

3 Conclusion

The spatio-temporal regression prediction model is a new method of using spatial data and time data to alternately convert the independent and dependent variables, moving forward to conduct prediction. Using this model to carry out short-term or long-term prediction on grain yield in Henan Province and all prefecture-level cities has some feasibility and effectiveness. Through the prediction, the grain yield of Henan Province in the year 2015 and 2020 is 59.849 6 and 67.929 3 million t respectively, consistent with the research results of other scholars to some extent, indicating the feasibility of this method.

By using spatio-temporal regression model, we predict the grain yield in Henan Province and all prefecture-level cities, at an interval of the same years, and based on this, predict year by year forward until the year we need. This prediction method is simple, the data amount is small and the information amount of prediction results is large. Researching and applying the current short-term regional data instead of long-term historical data, can conduct spatial and temporal prediction at the same time, with low cost of prediction. This overcomes the shortcoming that use time sequence method to conduct prediction needs long-term historical data. On the basis of alternate spatio-temporal regression moving prediction, the prediction model we establish is not fixed. Over time, new grain yield data emerge incessantly, so we can use new data to establish new spatio-temporal regression model, to make prediction results more accurate.

Factors affecting grain production in Henan Province are manifold. In order to ensure grain production, and meet the growing needs of economic development, the grain production in Henan Province should pay attention to the following aspects: protect amount of arable land resources; promote farmland quality; ensure grain planting area; increase agricultural inputs; strictly control population.

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problem of farmers. From the migration experience of Ningxia ecological area for over a decade, it is shown that better development of ecological areas is in reliance on big cities along Yellow River, industrial parks, and industrial base. Then, it is intended to achieve the mechanism of getting rich on the basis of income from distinctive crop cultivation and aquaculture and with labor service income as main part.

2.2 Scientific and complehensive ecological migration policy Ningxia has issued various policies to support agriculture and benefit farmers, and to motivate people to relocate and get rich. The ecological migration system mainly depends on policy and law systems of poverty alleviation and conceding the land to forestry, therefore, the design of system concerns the success of ecological migration. The ecological migration policy of Ningxia is very comprehensive. The immigrants moved to new areas will still be benefited from policy of conceding the land to forestry and grass. In the transition period of ecological migration, we should incorporate destitute households of immigrants into such social security system as local remedy, and secure those immigrants conforming to local minimum living standard. As to the housing of ecological migration, each household is provided with 54 m^2 house and 25 000 yuan subsidy. The rest will be raised by farmers themselves, but the farmers will have the property right. After relocation, the original house will be dismantled, and it is not allowed to hire out or transfer immigration houses within 10 years. Labor immigrants will be provided with 40 m^2 short-term house. The autonomous region will assume 70% of house costs, urban and county enterprises bear 30%. And the short-term house can be rented by immigrants, but immigrants should not transfer these houses. Land: the income from land in ecological migration area is the property of the State and managed by local competent authorities. For land arranged and developed by the ecological migration area, generally each person is provided with 0.067 hm^2 irrigated field, to support development of one mu of protected agriculture, and the original contracted land use right will be taken back. As to industrial support, every 0.067 hm^2 of large and medium-sized arc shed will be subsidized for 5 000 yuan, and every 0.067 hm^2 of green house will be subsidized for 8 000 yuan. Those planting potatoes and muskmelons by covering plastic film will be provided with 60 yuan for 0.067 hm^2 land, and those planting data trees and *Lycium chinenses* and other characteristic economic forest will be provided with 120 yuan for 0.067 hm^2 land. Social security: after relocation, the ecological immigrants and labor immigrants enjoy the same social security policies, including the same education, social remedies, social welfare and charities. Household register: principle of territorial jurisdiction is applied, and all administrative charges are free in the course of domiciliary transfer. Education: Immigrants' children, who fail to admit to senior high schools or fail to admit to universities or colleges, can be offered with a two-year free vocational technical education in vocational schools. These cover policies of land, housing, education and social security. So it dispels immigrants' worry and arouses immigrants' enthusiasm of relocation and development.

3 Conclusions

Proper development pattern and sufficient capital and perfect policy guarantee are the key to achieving the strategy to develop western regions and realizing goals of building beautiful land and all nations shaking off poverty, getting rich and live and work in peace and contentment.

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