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Forecasting Grain Production in Hubei Province Based on Markov Modeling

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Abstract. Grain production plays a crucial role in economic and social development. Accurate prediction of grain production can help agricultural decision-makers allocate resources rationally and do a good job at the next stage of the arrangements for the deployment of the work.This article used the production data, which was from 2023 Hubei Provincial Statistical Yearbook,to simulate and predict the grain production for several years,with the method of Markov prediction. It can be seen from the results that the average fitting error of the model is 3.47%. Using the text dataset of grain production from 2020 to 2022, the results show that the model can effectively improve the prediction accuracy of agricultural grain procuction. Finally, the model is used to predict the agricultural output value structure of China from 2023 to 2027. Markov prediction can improve the predictability and initiative of the work and provide scientific basis for the future decision-making of agricultural managers, and has guiding significance for the work of grain storage and distribution.

Keywords: Markov prediction, grain production, transition probability.

1. Introduction

Human survival and social progress depend on grain, and its production have a big impact on the food security system, which in turn relates to whether it can meet people's survival needs [1]. Stable grain production can not only satisfy people's daily needs, but also maintain social stability and promote economic prosperity. By ensuring sufficient grain supply, it can alleviate the problem of hunger, improve people's living standard, and promote social harmony and stability. Therefore, ensuring stable growth of grain production is not only an important part of the national development strategy, but also an inevitable choice for realizing sustainable development and building a harmonious society [2].

Hubei province is rich in resources and the level of grain production has remained stable for many years. It is not only the world's largest grain-producing province, but also always the largest net output of national grain transfer provinces, became the national agricultural granary [3]. In order to guarantee the food security and stable supply, the food production situation need to be judged in advance. Grain forecasting plays an important role in this field, it can be relatively accurate prediction of the future short-term food production, to provide an important reference for decision makers, such as the development of food policy, adjustment of agricultural production plans, arrangements for the import and export of food and so on [4]. Through food forecasting, decision makers can keep abreast of the

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food supply and demand situation and take corresponding measures to ensure national food security and market stability.

For a long time, domestic scholars and foreign scholars have invested great efforts in grain yield forecasting and studied the techniques to estimate grain yield accurately and efficiently. Domestic methods such as Time Series Analysis, Regression Analysis, Gray Relation Analysis (GRA) and Artificial Neural Network (ANN) model are commonly used [5]. Remote Sensing Statistical prediction methods, Crop Production models and Climate Productivity Models used abroad have shown strong applicability in the field of grain yield prediction [6]. However, the food production system is extremely complex, food from seeding to production of various links, are vulnerable to social, economic and natural factors, traditional methods in the prediction process is difficult to take into account the impact of many factors, so the prediction accuracy still needs to be improved [7]. Therefore, it is necessary to explore the change rule of grain yield, so as to scientifically and accurately predict the annual grain output.

Markov model is mainly used to analyze the future development and change trend of random events, that is, use the current state and trend of a variable to predict its future state and possible changes [8]. The future development trend can be predicted by Markov model through State transfer probability matrix, and can make long-term prediction for random fluctuation series [9]. In agricultural production, this year's grain output is only related to the output of the previous year, and has nothing to do with the past. Therefore, this article uses the Markov prediction model to predict the change of grain output in Hubei Province. By making statistics on the harvest of Hubei Province over the years and dividing the state to calculate the state transition probability matrix, the Markov prediction is reasonably applied to this process. It is found that the model has a high fitting accuracy for the grain output of Hubei Province in 2020-2022. It also predicts the change trend of grain production in the next five years, and provides an important theoretical basis for formulating the development plan of agriculture and issuing relevant policies.

2. Methodology

2.1. Data source

The data are from the 2023 Hubei Provincial Statistical Yearbook. These data not only clearly show the grain production in the past years, but also help to understand the trend of production change, which provides a key role for the scientific assessment and prediction of grain production in Hubei Province. Therefore, the results of this paper have certain scientific validity and credibility, and are of great significance in guiding agricultural production, policy making and food security (Table 1).

Table 1. Grain production and status in Hubei Province from1990 to 2019.

Year	Grain (10kt)	Status	Year	Grain (10kt)	Status	Year	Grain (10kt)	status
1990	2475.03	E4	2000	2218.49	E2	2010	2304.26	E3
1991	2244.10	E2	2001	2138.49	E2	2011	2407.45	E4
1992	2426.60	E3	2002	2074.00	E1	2012	2485.14	E4
1993	2325.70	E3	2003	1921.02	E1	2013	2586.21	E4
1994	2422.10	E3	2004	2100.12	E1	2014	2658.26	E5
1995	2463.84	E3	2005	2177.38	E2	2015	2914.75	E5
1996	2484.40	E4	2006	2099.10	E1	2016	2796.35	E5
1997	2634.40	E4	2007	2139.07	E2	2017	2846.12	E5
1998	2475.79	E4	2008	2145.47	E3	2018	2839.47	E5
1999	2451.88	E2	2009	2291.05	E3	2019	2724.98	E5

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2.2. Selection of indicators

In this article, the grain production data of Hubei Province from 1990 to 2022 were selected. The data from 1990-2019 is the training dataset, and the data from 2020-2022 is the test dataset (Table 2).

The maximum value of this data set is 28,394,700 tons and the minimum value is 19,210,200 tons, within which grain production is classified into five states.E1 is the year of arrears from1921.02kt to 2104.71kt.E2 refers to the year of low average income from 2104.71kt to 2288.4kt.E3 is the average year from 2288.4kt to 2472.09kt.E4 is a flat bumper year from 2472.09kt to 2655.78kt.E5 is the harvest year from2655.78kt to 2839.47kt.

Table 2. Harvest status and counts.

Harvest status	Number of times
E1	4
E2	6
E3	8
E4	6
E5	6

2.3. Method introduction

2.3.1. Markovian prediction models. Markov forecasting model is a kind of analytical method to predict the future state and movement of a variable by using the present state and movement of the variable. The difference between it and other statistical methods, such as regression analysis, gray prediction, etc. When other methods are used, common links need to be found among complex predictors, but Markov prediction model only focus on the historical state of the event, through the calculation of the state transfer probability matrix to get the results of the internal state change. So the Markov model in the actual prediction has been widely used.

2.3.2. Markov processes and markov chains. In the process of system state transition, when the state of the system at time t is known, the state of the system at the future time is only related to the state of the system at time t, but not to the state of the system before time t. This property is called no aftereffect [10]. A state transition process with no aftereffect is called a Markov process. A series of Markov processes form a Markov chain

2.3.3. State transfer probability matrix and calculation. The system has n mutually incompatible states $S_1, S_2, \dots, S_n$, and each time can only be in one state $S_j(\mathrm{j} = 1,2,.,\mathrm{n})$. After Δ t time, state S_j has n kinds of transition possibilities. Corresponding to the n states of the system, the possibility of n kinds of transition needs to be described by n × n transition probabilities $p_{\mathrm{i}j}$ $(\mathrm{i},\mathrm{j} = 1,2,.,\mathrm{n})$, $p_{\mathrm{i}j}$ represents the probability of the system's transition from state i to state j, so $p_{\mathrm{i}j}$ forms a transition probability matrix of order n × n, and the transition probability matrix formed in this way is called the one-step state transition probability matrix, which is recorded as p [11].

$$P = \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ p_{n1} & p_{n2} & \cdots & p_{nn} \end{pmatrix} \tag{1}$$

Satisfying conditions:

$$0 \le p_{ij} \le 1 \ (i,j = 1,2,.,n) \tag{2}$$

$$\textstyle\sum_{j=1}^{n} p_{ij} = 1 \tag{3}$$

In this article, the method of estimating probability by frequency counts was adopted, and the state transfer matrix is derived as:

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$$P = \begin{pmatrix} 0.5 & 0.5 & 0 & 0 & 0 \\ 0.34 & 0.33 & 0.33 & 0 & 0 \\ 0 & 0 & 0.71 & 0.29 & 0 \\ 0 & 0.29 & 0 & 0.57 & 0.14 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \tag{4}$$

Initial state: S (0) = [0.13 0.2 0.27 0.2 0.2].

2.3.4. Error analysis. The relative error of the predicted values calculated by the Markov decision-making prediction method is compared with the actual values to examine the prediction accuracy, which is calculated by the following formula:

$$\text{Relative error } = \frac{|\text{Predicted value} - \text{Actual value}|}{\text{Actual value}} * 100\% \tag{5}$$

3. Results and discussion

3.1. Prediction results

After program calculation, the calculated results are shown in the following table 3:

Table 3. Finite sub-state transfer distributions.

Year	E1	E2	E3	E4	E5
2020	0.0512	0.0703	0.0904	0.0661	0.7220
2021	0.0495	0.0680	0.0874	0.0639	0.7312
2022	0.0479	0.0657	0.0845	0.0618	0.7402
2023	0.0463	0.0635	0.0817	0.0597	0.7488
2024	0.0447	0.0614	0.0789	0.0577	0.7572
2025	0.0433	0.0594	0.0763	0.0558	0.7653
2026	0.0418	0.0574	0.0738	0.0539	0.7731
2027	0.0404	0.0555	0.0713	0.0521	0.7806

In order to show the prediction results more clearly, the obtained data are visualized as follows (Figure 1):

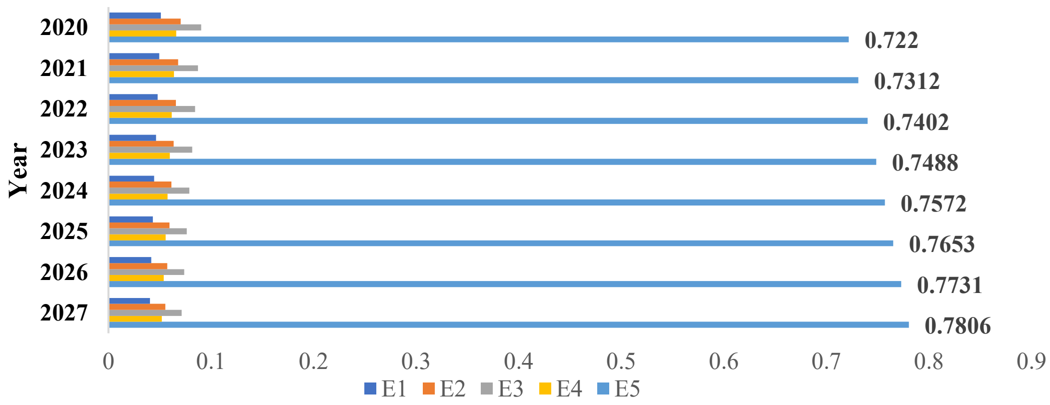

Figure 1. Forecast results of each state from 2020 to 2027.

According to the calculation results. The probability of each harvest state in 2020 is 0.0512, 0.0703, 0, 0904, 0, 0661, 0.722. The probabilities of each harvest state in 2021 were 0.0495, 0.068, 0.0874,

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0.0639, 0.7312, respectively. The probability of each harvest state in 2022 is 0.0479, 0.0657, 0.0845, 0.0618, 0.7402, respectively.

It can be intuitively observed from the figure that the probability of Hubei Province's grain production harvests E1, E2, E3, and E4 from 2020 to 2027 has declined to varying degrees year by year. The probability of the state being E1 has dropped to less than 5% in 2027, and the probabilities of the states being E2, E3, and E4 are 5.55%, 7.13%, and 5.21% respectively in 2027 which present relatively low probabilities. However, the probability of being in E5 status increases every year, even reaching 78.06% in 2027, an increase of nearly 6% in eight years.

3.2. Error calculation

Error analysis is a very important part of the Markov prediction model, which can clearly demonstrate the accuracy and fitting degree of the prediction results. From Table 4 and Figure 1, it distinctly shows that in 2020, 2021 and 2022, the grain production of Hubei Province has 72.2%, 73.1% and 74.0% probability of exceeding 28,394,700 tons respectively. Taking the data from 2020 to 2022 as the test data set, the error result is obtained through the calculation of Formula (5).

Table 4. Relative error calculations.

Year	Actual value	relative error
2020	2727.43	4.10%
2021	2764.33	2.72%
2022	2741.15	3.59%

Through error calculation, it can be seen from Table 4 that the error in each year is less than 5% and the average error in three years is calculated to be 3.47%, which means that the Markov prediction model has a high accuracy in predicting grain production.

Combining the prediction results and errors, it can be seen that the Markov prediction model has both high fitting accuracy and high prediction accuracy for the prediction of grain production, which can effectively improve the prediction accuracy of grain output in Hubei Province because of its simple calculation and high practicality in practical applications.

It can be seen from Table 3 that in the next five years, the probability of grain output in Hubei Province in E5 state will steadily increase year by year, with a good development trend.

4. Conclusion

The results show that the Markov forecasting method can forecast the short-term trend of grain production in Hubei Province, and the development trend of the recent stage has been tested to be consistent with the actual situation, and the actual grain production of the previous stage can be utilized to forecast the grain production of the next stage in the subsequent year-by-year forecasts. Because of its method is simple and easy to implement, and is a short-term state prediction method, only by the influence of the previous stage of the data change is small, so it is suitable for agricultural information management in the statistical work, the stage of the trend prediction, the agricultural work of the future evolution of the scientific speculation, to guide the agricultural decision makers to do a good job at the next stage of the arrangements for the deployment of the work. However, the Markov decision-making forecasting method is only a rough speculation, if this paper wants to get accurate results, the author should choose appropriate forecasting models in combination with specific situations, and compare and analyze with seasonal trend forecasting models, time series forecasting models, gray series models and other forecasting methods. This will make the results more scientific, standardized and rationalized, give full play to its positive role in agricultural management decision-making, and help agricultural managers to rationally allocate resources and improve the management system.

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