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Application of Markov Chain in Single Yield of Sorghum

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Abstract **Review Article**

The single yield of sorghum is affected by many factors and has the characteristics of large random volatility. It is proposed to use Markov chain method to predict the yield of sorghum, and based on the data of sorghum single yield in Jilin Province. In 2004, the provincial sorghum yield was predicted and its effectiveness was verified.
Keywords: Markov chain; Sorghum single yield; transfer matrix.

INTRODUCTION

Food is one of the important conditions for human survival. To a certain extent, the output of food also determines the economic development and social stability of a country, and it can also reflect the social security capacity of a country. China is an important agricultural country in the world, and jilin province is one of the important grain production bases in China. The change of grain output directly affects the fluctuation of national farmers' economic income, as well as the security of China's grain supply and demand. Based on the markov chain prediction model, this paper studies the single sorghum yield data from 1985 to 2004 in jilin province, and describes the change rule of single sorghum yield, which provides valuable reference for farmers and related agricultural departments.

The establishment of Markov Chain Model

Markov process is a kind of random process without aftereffect. The object of markov chain prediction is the dynamic system with random change. It predicts the future development of the system according to the transition probability between states [1, 2]. The specific steps to predict the single yield of sorghum in jilin province by using markov chain method are as follows:

Step-1 State division: According to the application experience and actual situation of markov chain analysis method, according to the change trend of annual sorghum single yield, sorghum single yield is divided into several states;

Step-2 Establish the transition probability matrix: According to the statistics of the results obtained in Step-1, the transition probability matrix of Markov chains with different delay times (step sizes) can be obtained. The formula of calculating the state transition probability matrix is $P_{ij} = N_{ij} / N_i$, $i,\ j = 1,\ 2,\ \cdots,\ s$, P_{ij} is the probability of going from state E_i to state E_j in one step, N_i is the number of occurrences of state E_i, N_{ij} is the number of times that state E_i transits to state E_j in one step. Thus, the one-step state transition probability matrix is obtained as P, then the n-step transition probability matrix is $P^{(n)} = P^n$;

Step-3 Predict the probability of the single yield of sorghum for the year:

$$P_i^{(k)},\ i \in E,\ k = 1,\ 2,\ \cdots,\ m$$

Prediction of single sorghum yield in jilin province

The single sorghum yield of jilin province from 1985 to 2003 was selected as the original data (Table -1) for modeling and prediction.

Table-1: Jilin province in 1985-2003 single sorghum production data

Years	Production (kg/hm^2)	Years	Production (kg/hm^2)
1985	2847.8	1995	4478.2
1986	2666.8	1996	4976.7
1987	3382.6	1197	4152.5
1988	3850.0	1998	3673.7
1989	2986.7	1999	4930.0
1990	4479.9	2000	3973.7
1991	4275.0	2001	6184.1
1992	4285.7	2002	6274.4
1993	4089.6	2003	6439.1
1994	4928.1		

Step-1 State division

Using the mean standard deviation method to divide the states [3]. Find the average value of sorghum yield in Jilin Province from 1985 to 2003: $\bar{x} = 4405.6 kg/hm^2$

Unbiased estimate of standard deviation: $S = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} = 1078.6$

Then, the state division interval of the sorghum production is obtained by the grading standard, as shown in Table-2. The single-yield data of sorghum in Jilin Province is divided into five state spaces: Dafengnian, Fengnian, Pingnian, disaster years, major disaster years.

Table-2: Jilin province sorghum production index scale

Status	Level	Grading Standards	Production Interval (kg/hm^2)
5	Dafengnian	$\bar{x}+0.5s \le y$	$4944.9 \le y$
4	Fengnian	$\bar{x} \le y < \bar{x}+0.5s$	$4405.6 \le y < 4944.9$
3	Pingnian	$\bar{x}-0.5s \le y < \bar{x}$	$3866.3 \le y < 4405.6$
2	disaster years	$\bar{x}-1.0s \le y < \bar{x}-0.5s$	$3327 \le y < 3866.3$
1	major disaster years	$y < \bar{x}-1.0s$	$y < 3327$

The original data in Table-1 were classified according to the classification standards in Table-2 to determine the status of sorghum single yield in jilin province in each year, as shown in Table-3.

Table-3: 1985-2003 in Jilin province sorghum production index partition table

Years	Production (kg/hm^2)	Status	Years	Production (kg/hm^2)	Status
1985	2847.8	1	1995	4478.2	4
1986	2666.8	1	1996	4976.7	5
1987	3382.6	2	1197	4152.5	3
1988	3850.0	2	1998	3673.7	2
1989	2986.7	1	1999	4930.0	4
1990	4479.9	4	2000	3973.7	3
1991	4275.0	3	2001	6184.1	5
1992	4285.7	3	2002	6274.4	5
1993	4089.6	3	2003	6439.1	5
1994	4928.1	4			

Step-2 Establish the transition probability matrix

According to the corresponding state of each year in Table-3, according to the calculation of transition probability matrix, the transition probability matrix of each step size can be obtained as follows:

$$P^{(1)}=\begin{bmatrix}0.3333 & 0.3333 & 0 & 0.3333 & 0\\ 0.3333 & 0.3333 & 0 & 0.3333 & 0\\ 0 & 0.2000 & 0.4000 & 0.2000 & 0.2000\\ 0 & 0 & 0.5000 & 0.2500 & 0.2500\\ 0 & 0 & 0.2500 & 0 & 0.7500\end{bmatrix},$$

$$P^{(2)}=\begin{bmatrix}0.2222 & 0.2222 & 0.1667 & 0.3056 & 00833\\ 0.2222 & 0.2222 & 0.1667 & 0.3056 & 0.0833\\ 0.0667 & 0.1467 & 0.3100 & 0.1967 & 0.2800\\ 0 & 0.1000 & 0.3875 & 0.1625 & 0.3500\\ 0 & 0.0500 & 0.2875 & 0.0500 & 0.6125\end{bmatrix},$$

$$P^{(3)}=\begin{bmatrix}0.1481 & 0.1815 & 0.2403 & 0.2579 & 0.1722\\ 0.1481 & 0.1815 & 0.2403 & 0.2579 & 0.1722\\ 0.0711 & 0.1331 & 0.2923 & 0.1823 & 0.3212\\ 0.0333 & 0.1108 & 0.3238 & 0.1515 & 0.3806\\ 0.0167 & 0.0742 & 0.2931 & 0.0867 & 0.5294\end{bmatrix},$$

$$P^{(4)}=\begin{bmatrix}0.1099 & 0.1579 & 0.2681 & 0.2224 & 0.2417\\ 0.1099 & 0.1579 & 0.2681 & 0.2224 & 0.2417\\ 0.0681 & 0.0653 & 0.1265 & 0.1108 & 0.3449\\ 0.0481 & 0.1128 & 0.3004 & 0.1507 & 0.3881\\ 0.0303 & 0.0889 & 0.2929 & 0.1106 & 0.2126\end{bmatrix},$$

$$P^{(5)}=\begin{bmatrix}0.0893 & 0.1429 & 0.2789 & 0.1985 & 0.1696\\ 0.0893 & 0.1429 & 0.2789 & 0.1985 & 0.1696\\ 0.0444 & 0.0698 & 0.1923 & 0.0975 & 0.3117\\ 0.0536 & 0.1137 & 0.2925 & 0.1514 & 0.3888\\ 0.0397 & 0.0983 & 0.2256 & 0.1260 & 0.2457\end{bmatrix}.$$

Step-3 Forecasting the status of sorghum single production in Jilin Province in 2004

According to the single sorghum yield data of jilin province in 2003, 2002, 2001, 2000 and 1999 and the corresponding state transition probability matrix, the single sorghum yield of jilin province in 2004 was predicted, as shown in Table-4.

Table-4: Single sorghum yield prediction table of jilin province in 2004

Initial year	status	Time lag/year	$i=1$	$i=2$	$i=3$	$i=4$	$i=5$	Probability source
2003	5	1	0	0	0.2500	0	0.7500	$P^{(1)}$
2002	5	2	0	0.0500	0.2875	0.0500	0.6125	$P^{(2)}$
2001	5	3	0.0167	0.0742	0.2931	0.0867	0.5294	$P^{(3)}$
2000	3	4	0.0681	0.0653	0.1265	0.1108	0.3449	$P^{(4)}$
1999	4	5	0.0536	0.1137	0.2925	0.1514	0.3888	$P^{(5)}$
$P_i=\sum_{k=1}^{m}P_i^{(k)}, i\in E$			0.1384	0.3032	1.2496	0.3989	2.6256	

According to table 4, $\max\{P_i, i\in E\}=2.6256$ and at this point $i=5$. It can be seen that the corresponding state of single sorghum yield in jilin province in 2004 is 5. It belongs to Dafengnian, which is consistent with the actual value of 5236.9.

CONCLUSION

At present, domestic forecasting methods of grain yield mainly include input-output model [4], BP neural network method [5], regression model method [6], ARMA model [7], GM (1,1) forecasting method [8] and so on. Compared with them, the Markov chain model has the characteristics of wide prediction range, high reliability and reasonable and sufficient information utilization. The result of markov chain model is scientific and reliable.

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