

# Family Agricultural Planning based on Time Series and Multi-objective Optimization

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## Abstract

**In order to obtain the time-related data of the price and output of agricultural products through the network platform, and to predict the labor cost and income of agricultural products, this paper adopts the time series forecasting method, and calculates the expected labor cost and income of different agricultural products by using Matlab software based on the collected data of previous years. The expected labor cost and income of different agricultural products were calculated with MATLAB software. The multi-objective fuzzy stochastic optimization model was used to solve the problem, and the optimal planting area of crops was obtained by using linear programming correlation algorithm and Matlab software. At the same time, in order to provide farmers with a reasonable large-scale agricultural planting plan under the condition of sufficient land resources. We used the multi-objective fuzzy stochastic optimization model to solve the problem, and obtained the optimal planting area of crops by using linear programming correlation algorithm and MATLAB software.**

## Keywords

**Time Series Analysis; Multi-objective Fuzzy Stochastic Optimization; Ecological Cycle; Agricultural.**

## 1. Introduction

Under the situation of the spread of globalization and the steady improvement of national living standards, the demand for green agricultural and livestock products may usher in a new outbreak period. Traditional large-scale planting or breeding mode because of its greater risk of product quality. [1,2] In addition, the rural revitalization strategy advocated by the country and the urgent need to solve the problem of inadequate and uncoordinated development in various regions indicate that the family-based unit or small-scale personalized planting and breeding plan is expected to become a new economic growth point of the country.

It is of great significance to analyze and discuss the expected labor cost and income of different agricultural products and provide reasonable large-scale agricultural planting plan for farmers with sufficient land resources, which will guarantee the stable income of farmers and ensure the recycling of land resources to the maximum extent. [3,4]

This paper adopts the time series forecasting method, and calculates the expected labor cost and income of different agricultural products by using Matlab software based on the collected data of previous years. And used the multi-objective fuzzy stochastic optimization model to solve the problem, and obtained the optimal planting area of crops by using linear programming correlation algorithm and MATLAB software.

## 2. Time series prediction

The time series model is actually a regression model. On the one hand, we can recognize the continuity of the development of things, and use the data of the past time series for statistical analysis to predict the development trend of things. On the other hand, the randomness caused by accidental factors is fully considered. In order to eliminate the influence of random fluctuations, the historical data are used for statistical analysis, and the data are properly processed for trend prediction. [5,6] Generally,  $T_t$  is used to represent the long-term trend item,  $S_t$  is used to represent the seasonal trend item,  $C_t$  is used to represent the cyclical trend item, and  $R_t$  is used to represent the random disturbance item. There are several types of common deterministic time series models.

Additive model(1):

$$y_t = T_t + S_t + C_t + R_t \quad (1)$$

Multiplication model(2):

$$y_t = T_t \cdot S_t \cdot C_t \cdot R_t \quad (2)$$

Hybrid model (3-4):

$$y_t = T_t \cdot S_t + R_t \quad (3)$$

$$y_t = S_t + T_t \cdot C_t + R_t \quad (4)$$

Where,  $y_t$  is the observation record of the observation target, the mean value,  $E(R_t)=0$ ,  $V_{ar}(R_t)=\sigma^2$ . If within the forecast time range, there is no sudden change and the variance 2 of random change is small, and there is reason to believe that the past and present evolution trend will continue to develop into the future, the moving average method can be used for forecasting.

Let the observation sequence be  $y_1, \dots, y_T$ , take the moving average of the terms  $N < T$ . The formula for calculating one time moving average is(5):

$$\begin{aligned} M_t^{(1)} &= \frac{1}{N} (y_t + y_{t-1} + \dots + y_{t-N+1}) = \frac{1}{N} (y_{t-1} + \dots + y_{t-N}) + \frac{1}{N} (y_t - y_{t-N}) \\ &= M_{t-1}^{(1)} + \frac{1}{N} (y_t - y_{t-N}) \end{aligned} \quad (5)$$

The quadratic moving average is calculated by(6):

$$M_t^{(2)} = \frac{1}{N} (M_t^{(1)} + \dots + M_{t-N+1}^{(1)}) = M_{t-1}^{(2)} + \frac{1}{N} (M_t^{(1)} - M_{t-N}^{(1)}) \quad (6)$$

When the basic trend of the forecast target is fluctuating around a certain level, The prediction model can be established, and its standard error is (7)

$$S_E = \sqrt{\frac{\sum_{t=N+1}^{\tau} (\hat{y}_t - y_t)^2}{\tau - N}} \quad (7)$$

The average value of the most recent N period series is used as the prediction result of future periods. When the basic trend of the historical sequence changes little and there are many random changes in the sequence, the value of N should be larger, otherwise, the value of N should be smaller. [7,8] In data with a definite seasonal fluctuation period, the number of moving average items should be the period length. An effective method to select the best N value is to compare the prediction errors of several models, the one with the smallest standard error is better.

When there are both linear trend and periodic fluctuation in the series, the trend moving average method can be used to establish the prediction model(8)-(9).

$$\hat{y}_{m+\tau} = \alpha_{\tau} + \beta_{\tau} m \varepsilon, m = 1, 2, \dots \quad (8)$$

$$\alpha_{\tau} = 2M_{\tau}^{(1)} - M_{\tau}^{(2)}, \beta_{\tau} = \frac{2}{N-1} (M_{\tau}^{(1)} - M_{\tau}^{(2)}) \quad (9)$$

According to the above model, the reference data and results are given:

Table 1. Labor cost of crops

Time \ crops	wheat	com	soybean	peanut	cotton	apple
2008	133.19	176.98	88.32	233.15	527.08	1001.5
2009	145.64	192.61	103.53	254.83	568.18	1488.97
2010	178.83	235.1	115.31	319.61	728.25	1707.2
2011	225.68	295.49	136.38	399.15	858.21	1944.15
2012	291.4	398.4	177.5	533.59	1170.71	2519.85
2013	343.78	455.37	200.95	645.51	1359.84	2746.83
2014	364.77	474.68	216.73	678.07	1408.39	3186.83
2015	364.39	468.72	215.16	693.64	1387.75	3253.8
2016	370.99	458.1	218.11	695.08	1393.72	3369.15
2017	361.87	441.2	215.85	693.87	1353.72	3110.96
2018	350.76	433.52	204.27	691.58	1194.91	3065.22
2019	345.55	422.56	201.25	690.8	1144.85	2965.4

Table 2. Crop cash income

Time \ crops	wheat	corn	soybean	peanut	cotton	apple
2008	376.69	416.76	350.35	588.17	587.11	2806.09
2009	392.44	462.11	312.43	909.48	970.21	3766.6
2010	419.29	584.42	378.42	942.94	1773.91	6110.23
2011	459.95	686.04	372.54	1261.77	1121.34	5997.63
2012	437.13	730.79	435.44	1362.8	1281.79	5785.77
2013	460.64	680.69	383.92	966.56	1223.17	5258.11
2014	601.76	728.59	353.99	1029.67	747.24	5844.76
2015	542.89	522.95	265.07	1012.46	493.94	4339.18
2016	455.61	341.21	163.77	1178.58	937.26	3222.35
2017	532.02	425.66	237.27	966.52	895.74	4285.55
2018	358.79	446.35	157.46	940.49	777.29	4903.05
2019	340.05	456.11	154.27	875.91	822.3	5347.1

Table 3. The expected results

crops	wheat	corn	soybean	peanut	cotton	apple
Expected labor cost	352.73	432.43	207.12	692.08	1231.20	3047.20
Expected cash income	410.27	442.71	183.00	994.80	922.23	4419.40

According to data statistics and calculation, we found that some crops (such as soybean and cotton) could not guarantee the livelihood of farmers only by selling income, so it was necessary for the government to subsidize agriculture, rural areas and farmers. [9,10] If the country does not subsidize the livelihood of agriculture, rural areas and farmers, a large number of rural labor force will flow to urban work to make a living. Crops include food crops and cash crops. In order to ensure China's food demand, the government should stipulate that farmers must plant food crops (otherwise, farmers only choose to plant cash crops in the goal of maximizing profits) on the one hand; on the other hand, it should vigorously support and encourage farmers to diversify food crops both materially and spiritually. [11,12]

For the time and price historical series of some agricultural products, the basic trend changes greatly and there are many random changes, so the one-time average movement method has limitations. Based on the trend, the exponential smoothing method and the differential exponential smoothing method will be more accurate.

### 3. Multi-objective fuzzy stochastic optimization model

We consider fallow as a means of promoting land recycling. After eliminating the irrelevant and unreasonable data, the multi-objective fuzzy stochastic optimization model was used for point-splitting processing. Specific steps are as follows:

1. Determine the relative membership matrix;
2. Determine the relative superior degree of target;
3. Establish a multi-objective fuzzy stochastic optimization model;
4. Determine the minimum and maximum planting area of each crop;
5. Solve the optimal planting area through the established model.

It is assumed that N kinds of crops need to be planted, and their scheme set is as follows:

$$X = [x_1, x_2, \dots, x_n] \tag{10}$$

The quadratic moving average is calculated by

$$S = [s_1, s_2, \dots, s_n] \tag{11}$$

Let the optimization model have m goals, which constitute the goal set. For scheme  $x_k$  ( $k = 1, 2, \dots, n$ ), the evaluation is carried out according to the  $i$ th target  $S_i$ , and the evaluation value obtained is denoted as  $x_{ik}$ , so that  $x_k$  can be expressed as (12):

$$x_k = \{x_{1k}, x_{2k}, \dots, x_{mk}\}^T \tag{12}$$

It can be represented by an m by n matrix

$$X = (x_{ik})_{m \times n} \tag{13}$$

The benefit target is the bigger the better target, and the cost target is the smaller the better target. In practical application, the physical dimensions of targets are often different, so relative membership matrix should be established to avoid the influence of different dimensions on optimization problems

$$R = (\gamma_{ik})_{m \times n} = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \dots & \gamma_{1n} \\ \gamma_{21} & \gamma_{22} & \dots & \gamma_{2n} \\ \dots & \dots & \dots & \dots \\ \gamma_{n1} & \gamma_{n2} & \dots & \gamma_{nn} \end{bmatrix} \tag{14}$$

When the goal is bigger is better

$$\gamma_{ik} = \frac{x_{ik} - \min x_k}{\max x_k - \min x_k} \tag{15}$$

When the goal is the smaller the better

$$\gamma_{ik} = \frac{\max x_k - x_{ik}}{\max x_k - \min x_k} \tag{16}$$

Generally speaking, different objectives have different status in the optimization, and different weights should be given to reflect their importance. Let the target weight vector be

$$w = [w_1, w_2, \dots, w_n] \tag{17}$$

In the multi-objective programming problem, if the target has a high relative membership degree to the optimal in the overall optimization, then the objective status of the target will be high, which will usually attract more attention and be given a greater weight value.

$$W = R^T = \begin{bmatrix} \gamma_{11} & \gamma_{12} & \dots & \gamma_{1n} \\ \gamma_{21} & \gamma_{22} & \dots & \gamma_{2n} \\ \dots & \dots & \dots & \dots \\ \gamma_{n1} & \gamma_{n2} & \dots & \gamma_{nn} \end{bmatrix} \tag{18}$$

The relative membership matrix of the target to the fuzzy concept of "importance" is obtained The relative membership vector of target  $S_i$  to "importance" is

$$w(i) = [w_{1i}, w_{2i}, \dots, w_{ni}]^T \tag{20}$$

The weight of target  $W_i$  ( $i = 1, 2, \dots, m$ ) is calculated as

$$w_i = \frac{1}{1 + \left[ \frac{\sum_{k=1}^n (1 - w_{ki})}{\sum_{k=1}^n w_{ki}} \right]^2} \tag{21}$$

According to the two-level fuzzy optimization model, the relative superior degree  $U_k$  ( $k = 1, 2, \dots, n$ ) of scheme  $k$  to the optimal comprehensive benefits can be calculated as follows

$$w_i = \frac{1}{1 + \left[ \frac{\sum_{k=1}^n (1 - \gamma_{ki})}{\sum_{k=1}^n \gamma_{ki}} \right]^2} \tag{22}$$

Based on the data obtained above, a multi-objective fuzzy stochastic optimization model of crop planting structure was established. The objective function is

$$\max V = \sum_{k=1}^n u_k a_k \tag{23}$$

Whereinto,  $a_k$  is the optimal planting area of crop  $k$  ( $k = 1, 2 \dots n$ ), and the optimal planting area vector is denoted as

$$a = [a_1, a_2, \dots, a_n] \tag{24}$$

The objective function is solved under the following constraints:

1. Area constraint

$$\sum_{k=1}^n a_k \leq A \tag{25}$$

$$\min a_k \leq a_k \leq \max a_k \tag{26}$$

Where,  $A$  is the total amount of available arable land area, and  $\min A_k$  and  $\max A_k$  are the minimum and maximum planting areas of crop  $K$  respectively, which are determined by market demand, independent demand or expert experience

2. Water constraint

$$\sum_{k=1}^n b_k a_k \leq B \tag{27}$$

Where, B<sub>k</sub> is the irrigation quota of crop K, and B is the total amount of agricultural water available

3. Cost constraints

$$\sum_{k=1}^n c_k a_k \leq C \tag{28}$$

Where, C<sub>k</sub> is the cost per unit area of planting crop K, and C is the total amount of available agricultural funds.

4. Constraint of human demands

$$\sum_{k=1}^n d_k a_k \leq D \tag{29}$$

Where, D<sub>k</sub> is the artificial number required by unit area of crop K in a certain period, and D is the total amount of artificial amount available for agriculture in the corresponding period.

5. Minimum income constraints

$$\sum_{k=1}^n e_k a_k \geq E \tag{30}$$

Where, E<sub>k</sub> is the net income per unit area of crop K in a certain period, and E is the minimum total income stipulated by agriculture in the corresponding period.

6. Non-negative constraints

$$a_k \geq 0 \tag{31}$$

Assume cultivation time  $\tau_1$  and fallow time  $\tau_2$ . For crop I, the cost of planting is  $c\tau(1i)$  and the cost of fallow is  $c\tau(2i)$ , the economic benefit of planting time  $\tau_1$  is  $Ep\tau(1i)$ , and the economic benefit of fallow time  $\tau_2$  is  $Ep\tau(2i)$ , and the calculation formula is

$$EP_{Ti}^{(i)} = \frac{\text{government subsidies-opportunity cost}}{\text{opportunity cost}} \tag{32}$$

$Ep(I)$ , the economic benefit of crop I, which is modified according to the weighting of planting time and fallow time, is

$$EP^{(i)} = \frac{\tau_1 \cdot EP_{T1}^{(i)} + \tau_2 \cdot EP_{T2}^{(i)}}{\tau_1 + \tau_2} \tag{33}$$

According to the data shown in Table 4 below, the following results were obtained by using MATLAB.

Table 4. Comparison of quantitative indexes of different crops

crops		wheat	corn	patato	soybean
cost of demand	initial	10900	10450	8610	8490
	fallow	2290	2290	2290	2290
	correction	4791	5935	6133	4461
Economic benefits	initial	3589	5305	5602	3093
	fallow	7196	7196	7196	7196
	correction	4791	5935	6133	4461
Degree of commercialization		80	40	20	15

$$u = (0.1023, 0.4842, 0.9454, 0.3792) \tag{34}$$

Secondly, according to the experience of experts, we obtained the maximum and minimum planting areas of the four crops and their artificial demands, as shown in Table 5-6.

Finally, multi-objective fuzzy stochastic optimization is carried out according to the above data, The optimal solution is

$$a = 10^3(3.8172, 3.8205, 2.5800, 1.5000), \max V = 5.2483 \times 10^3 \quad (35)$$

Table 5. The maximum and minimum planting area of crops

Crop type	Spring wheat	Spring corn	soybean	potato
Minimum planting area	850	920	1622	1500
Maximum planting area	5967	4985	2580	2410

Table 6. Artificial demand for crops

Crop type	Spring wheat	Spring corn	soybean	potato
Artificial demand	50	35	41	40

We adopt a multi-objective fuzzy random optimization model, calculated the optimal size and relative membership matrix, finally converted into linear programming problem to solve, in the process of building model, we simplify the model, without considering the environmental benefits of the agricultural products, but to ensure that land fallow recycling, there will have some error.

#### 4. Conclusion

Optimal from relatively speaking, the optimal relative of wheat is lower than other kinds of crops, this is because the economic benefits of wheat is low, the cost of demand on the high side so the efficiency target and cost target value is very low, so the wheat crops in our model belongs to the planting of crops is not recommended (without considering national policy subsidies). However, cash crops such as potato are highly recommended in the model. From the point of the optimum planting area, the actual results with our vision, on the other hand, although the wheat from the economic perspective is not high, but the market demand is very big, commercialization degree is high, this is because the wheat, as one of the three major staple foods, no matter from the perspective of national food security or from the perspective of individual be fond of all requirements of its production is very high. In this multi-objective fuzzy stochastic optimization model for integrated test a variety of factors, combining the resources of data, obtained under the condition of land information is sufficient, guarantee the farmers' income and make the land as far as possible to recycle the planting plan, which takes into consideration the fallow situation, make the circulation utilization of land, planted crops safeguard farmers' income, but also take into account the food crops.

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