Research On Crop Planting Optimization Based On Yield And Profit Analysis

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Abstract. With the development of agricultural modernization, data-driven crop cultivation decision models have performed well in addressing challenges such as climate change, market fluctuations, and resource constraints, becoming an important means of improving yields, optimizing structures, reducing costs, and achieving maximum crop revenue. In this study, we selected corn, pork, soybeans, and live cattle as the futures composite indicators from commodity futures, using data from January, March, June, and the beginning of September 2024, and integrated and differenced the data before using time series models to predict the approximate prices of agricultural products for 2025 and beyond. We combined the Monte Carlo model to provide the optimal cultivation plan, predicting that the estimated profit of vegetable-type farm products in the first quarter of 2025 is 0.88 million yuan. This model is capable of conducting yield predictions for various types of farmland and offering individualized planting strategies in accordance with the specific characteristics of different farmlands.

Keywords: Crop Market, Linear Programming, Monte Carlo, Parameter Optimization.

1. Introduction

With the development of agricultural modernization, data-driven crop cultivation decision models have performed well in addressing challenges such as climate change, market fluctuations, and resource constraints, and have become an important means of improving yields, optimizing structures, reducing costs, and maximizing crop revenue. This study takes commodity futures, specifically corn, pork, soybeans, and live cattle, as the integrated futures indicators, and uses data from January, March, June, and early September 2024 to integrate and differentially process the data, using time series models to predict crop yields for 2025 and beyond. How to maximize crop yields through scientific and rational cultivation decisions has become an important topic in the current field of agricultural production, especially in the context of climate change, fluctuations in market demand, and limited land resources[1,2]. How to improve crop yields, optimize crop structures, reduce costs, and increase profits is an urgent problem that farmers and decision-makers need to solve[3,4]. With profit maximization as the goal, and using the cyclical nature of various crop cultivation, a cultivation strategy can be derived. To address these challenges, data-driven decision models have been widely applied in agriculture[5,6].

For this study, the Monte Carlo algorithm will be used to confirm the optimal solution. This algorithm was invented by von Neumann and others, and is currently widely used for model optimization and solution in large sample spaces, such as crop cultivation, simulated light transmission, and financial investment decision-making, and has high accuracy in the face of large sample sizes. At the same time, to accurately calculate the future economic output of crops, the ARIMA time series model will be used for calculation. This algorithm was invented by Box and others, and is currently widely used for simulated prediction of data with obvious time features, such as crop price prediction and stock trend prediction, and has high stability in predicting data with obvious time features.

In the research process, the data will be integrated and differentially processed first, and the average profit and total profit of grain crops, vegetables, and edible fungi will be compared to establish the objective function and establish the constraint conditions[7,8]. The linear programming method will be used to ensure soil fertility and achieve sustainable cultivation, and the optimal crop planting scheme under the condition of unchanged prices was obtained. After that, it was further optimized to establish the price fluctuation range, the overall trend of price adjustments, and other uncertain factors, and the crop planting scheme under the condition of price changes was obtained. Finally, the expected profit of agricultural products was calculated[9,10].

2. Data Sources and Visualization Analysis

Data in this study are derived from https://www.mcm.edu.cn/. The price range of each crop is varied and averaged to get the selling price. Assuming that sales are expected to be the same as production, calculate the profit per acre that different crops can produce. Then the distribution of unit price of sales of three kinds of different crops is analyzed. The costs of different crops were then compared with their profits. Finally, the average profit and total profit of different types of crops were compared respectively[11,12].

According to the analysis, the profit output of white mushrooms is the largest, higher than 250000 yuan per mu; For Small green vegetables, lettuce profit output followed, close to 100,000 yuan per mu; The profit output of spinach, yellow heart, cauliflower, etc., is small, less than 50,000 yuan per mu; Soybean, wheat, pumpkin, black beans and other agricultural products have almost zero profits. Soybean, wheat, pumpkin, black beans, and other agricultural products have almost zero profits.

The distribution of the unit sales price of grain and vegetables is not much different in general, and the unit sales price is at a low level the distribution is concentrated, and the variance is low. The average selling price of edible fungi was higher, but its variance was higher.

For example, soybean, corn, sweet potato, and other grain crops are mainly distributed in dry land, terraces, hillsides, and other one-season production areas, and the economic added value is low; Such as cowpea, rye, and other vegetables are mainly distributed in irrigated land and other two seasons of production, the economic added value is high; Fungus crops are mainly planted in greenhouses with high economic added value. All three crop types cost about the same.

Fungal crops belong to high value-added products with high unit profit. When formulating strategies, it is necessary to give priority to planting fungal crops to maximize profits.

Figure 1 shows the forecast of commodity futures between 2024 and 2025, and Figure 2 shows the forecast prices of some crops between 2024 and 2025.

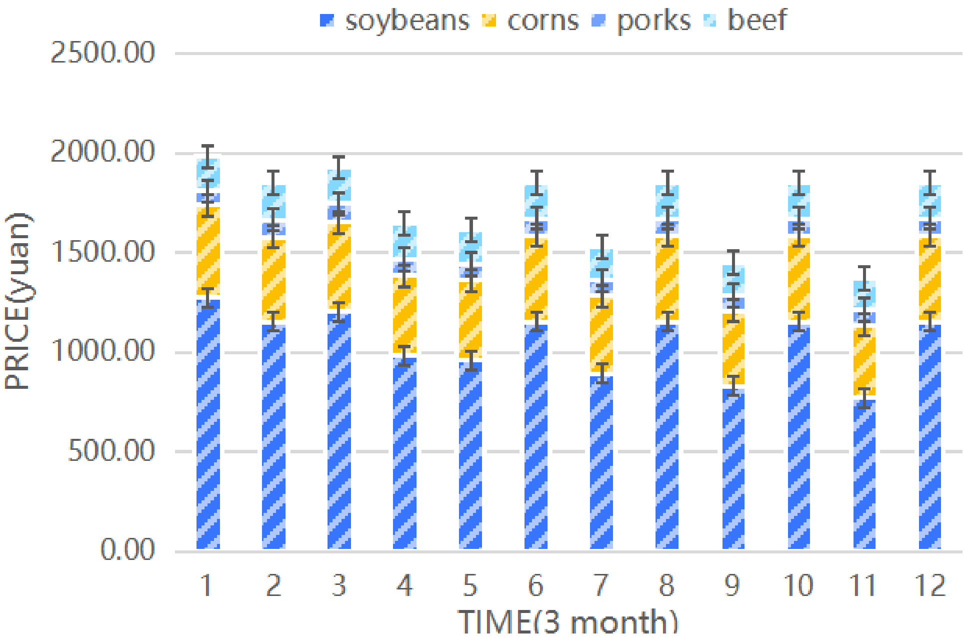

Figure 1. Futures price forecast

The abscissa indicates the different periods from January 2024 (every three months), and the ordinate represents the economic benefit (yuan).Among them, corn and soybeans are priced in tons, and pork and beef are priced in kilograms.

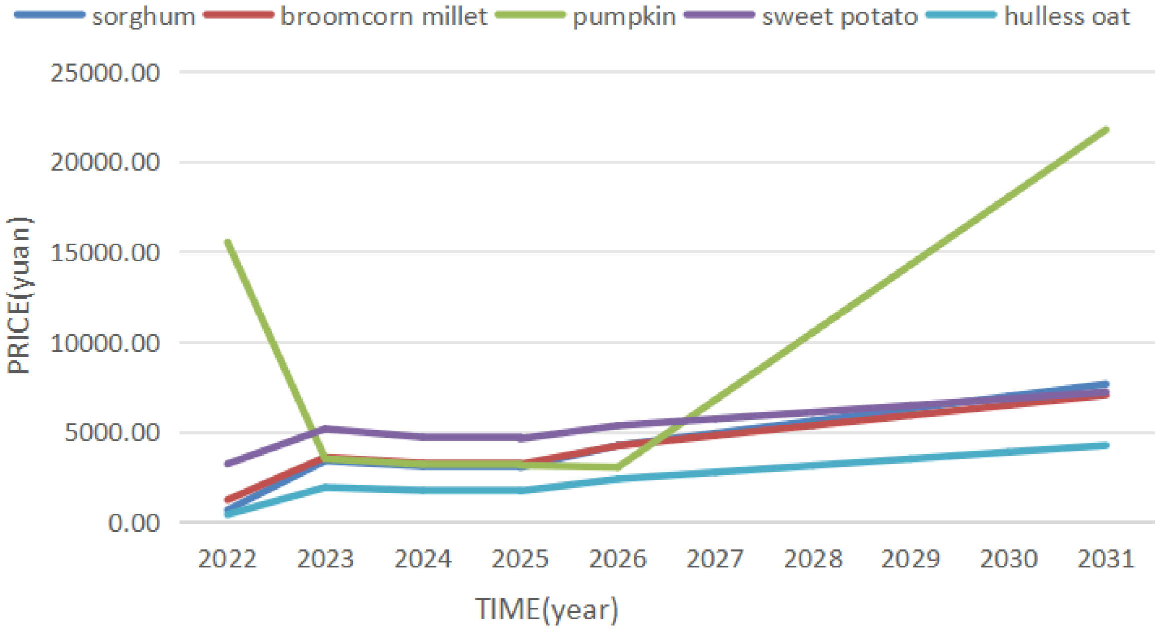

Figure 2. Agricultural product price forecast

The abscissa indicates the number of the experimental fields, and the ordinate represents the economic benefit (in yuan) that can be generated per mu of land(yuan).

3. Establishment and solution of crop planting decision optimization model

3.1. The objective function establishment

(1) This function can be used to calculate the maximum profit of crop cultivation in the area over some time.

(2) This model can be used to calculate crop profits under uncertain conditions.

$$\text{MaxmizeW} = \sum_{h=1}^{H}\sum_{s=1}^{S}\sum_{t=1}^{2}\left(p_s.q_s.A_h.x_{h,s,t} - c_{h,s}.A_h.x_{h,t,s}\right) \tag{1}$$

$$\min\sum_h\sum_s\sum_t = \left(p_{h,s,t}.\min\left(Q_{h,s,t,}D_{h,s,t}\right) - c_{h,s,t}.x_{h,s,t}\right) \tag{2}$$

3.2. The establishment of constraint conditions

Formula (3) shows that the sales of wheat and corn have an annual growth rate of 5% to 10%,Formula (4) is the change in sales of other crops by ±5%,Formula (5) indicates that the per mu yield of crops changes by ±10% per year,Formula (6) shows that the price of food crops is basically stable,Formula (7) shows that the price of vegetable crops increases by 5% per year,Formula (8) is that the price of edible fungi crops decreases by 1%-5%,Formula (9) is an average annual increase of 5% in planting costs.

$$D_{h,s,t} = D_{h,s,2003} \times \left(1 + r_{h,s,t}\right)^{t-2023}, \forall h \in \{z_6, z_7\} r_{h,s,t\in}[0.05,0.1] \tag{3}$$

$$D_{h,s,t} = D_{h,s,2003} \times \left(1 + \delta_{h,s,t}\right)^{t-2023}, \forall h \in \{z_{1-5}, z_{8-41}\}\ \delta_{h,s,t}\epsilon[-0.05,0.05] \tag{4}$$

$$q_{h,s,t} = q_{s,2023} \times \left(1 + \eta_{s,t}\right)^{t-2023}, \eta_{h,s,t}\epsilon[-0.1,0.1] \tag{5}$$

$$p_{h,s,t} = p_{h,s,2023}, \quad \forall h \in \{z_1{\sim}z_6\} \tag{6}$$

$$p_{h,s,t} = p_{h,s,2023} \times (1.05)^{t-2023}, \quad \forall h \in \{z_{17}{\sim}z_{37}\} \tag{7}$$

$$p_{h,s,t} = p_{h,s,2023} \times \left(1 - y_{h,s,t}\right)^{t-2023} \quad , \quad \forall h \in \{z_{38\sim} z_{41}\}\ y_{h,s,t} \epsilon [0.01, 0.05] \tag{8}$$

$$c_{s,t} = c_{s,2023} \times (1.05)^{t-2023} \tag{9}$$

In summary, by refining constraint conditions to better align with real-world scenarios, this study provides a basis for solving optimal planting schemes and subsequent profit calculations.

4. Results

4.1. The establishment of the decision model (1)

Assume that the sales volume of each crop will fluctuate up or down by a range of 10%. In the process of model building, the production strategy is formulated with the maximum increase range of sales in 2023, i.e. 110% of sales volume, as the target sales volume, to ensure that the crop yield is always greater than the actual demand of the people.

In the objective function, 90% of the sales volume is regarded as the real sales volume, which is applied to the objective function (formula 1), the loss caused by the remaining part is obtained, and two kinds of loss treatment are classified: slow sales or 50% sale price.

Taking the next three years as the analysis base period, the planting strategy for the next n years is cyclic in three years to ensure that bean crops are planted every week to maximize planting profits.

4.2. Analysis of experimental results (1)

Table.1. 2025 Planting Decision Table (Part)

filed crops	Sorghum	Glutinous corn	buckwheat	pumpkin	Sweet potato	hulless oat
A	80	0	0	160	0	0
B	55	0	0	0	0	0
C	35	0	0	0	0	0
D	216	0	0	0	0	0
E	68	68	0	0	0	0
F	55	0	55	0	0	0
G	60	60	0	0	0	60
H	46	0	0	0	0	0
I	40	0	0	0	0	0
J	28	0	0	0	0	0
K	25	0	0	0	0	0
L	86	0	0	0	172	0

The results of this model can provide farmers with planting strategies and what crops are more suitable to grow in China now. As shown in Table 1, sorghum is the most widely planted in the test field, with 794 acres planted in 2024. Field G is planted with three crops, showing the diversity of crop cultivation.Pumpkins are only grown in field A and sweet potatoes are only grown in field L.

4.3. The establishment of a decision model (2)

Further, considering that the sales volume, price, planting cost, and mu yield data of various agricultural products all fluctuate within a certain range, comprehensively considering the uncertainty of these factors and the planting risk of crops, the futures data of four commodities, corn, pig, soybean and live cattle, are simulated to simulate the downward market of crops. The grey prediction GM(1,1) model and time series analysis (ARIMA) were used to predict the downside market data. The data is calculated according to the formula to find the change ratio, and finally the profit in 2025.

4.4. Analysis of experimental results (2)

Table.2. 2024-2025 Planting Profit Table

category time	2024.1	2024.2	2025.1	2025.2
cereals	1218938.08	0	814274.38	4500
vegetables	505892.81	-206176.5646	879457.13	-206176.56
mushrooms	0	53494.09	0	53399.08

As can be seen from the above Table.2, under the premise that the expected sales volume and yield per mu of agricultural products are all uncertain, the profit of grain agricultural products in the first quarter of 2024 is 1.22 million yuan, and the profit of vegetable agricultural products in the first quarter of 2025 is 0.88 million yuan.

5. Conclusions

This study integrated and processed data on food, vegetable, and edible fungi agricultural products to compare average and total profits. Findings indicate that while the planting volume of food crops is higher than that of vegetables, the average profit of fungi is significantly higher than that of both food and vegetable crops. Using linear programming, we developed objective functions and constraints to establish the optimal crop planting plan over the next seven years, ensuring a steady weekly pulse crop yield. Corn, pig, soybean, and live cattle futures data were analyzed as comprehensive indicators, with time series and grey forecasting models used to predict price trends for 2025 and derive agricultural product profits for 2024 and 2025. Additionally, the profit trends over the next seven years were analyzed, and uncertainties were factored into a Monte Carlo model to yield the optimal planting strategy, with expected profits for vegetable crops projected to reach 0.88 million yuan in 2025.

Future research could expand this model by integrating factors such as climate change, natural disasters, and policy shifts to better account for agricultural uncertainties. Additionally, incorporating dynamic adjustments would enhance the model’s adaptability to evolving market conditions. Examining the socio-economic impacts of optimized planting strategies on rural communities could also offer insights into the broader benefits of agricultural planning. These improvements would refine the model's practical utility, supporting data-driven decisions and promoting sustainable agricultural development.

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