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THE OPTIMAL YIELD PROBLEM OF CROP PLANTING BASED ON LINEAR PROGRAMMING MODEL

Jie Deng[1], Jian Wang[1], Hao Xu[1], ZhengBo Li[2*]
[1]*Department of Brewing Engineering, MouTai Institute, Renhuai 564500, GuiZhou, China.*
[2]*Department of Public Basic Education, MouTai Institute, Renhuai 564500, GuiZhou, China.*
Corresponding Author: ZhengBo Li, Email: wxxtedu@sina.cn

Abstract: The optimal income problem of crop planting is controlled by various uncertain factors. By controlling for uncertain factors, the problem of crop income can be summarized as the optimization problem of crop planting structure. Reasonable optimization of crop planting structure has an important impact on the economic status of regional farmers, sustainable development of agriculture, and sustainable utilization of land resources. The crop planting structure includes both temporal and spatial structures. Therefore, this article constructs a mathematical model combining linear programming and Monte Carlo method by analyzing the two types of land structures. Firstly, use linear programming to simulate various constraints in crop planting structure, and then increase the randomness in time structure through Monte Carlo method. At the same time, this article also explores the correlation between crop yield per mu, planting cost, and sales price through heat maps, in order to help decision-makers better analyze crop planting structure and improve crop planting income. The results indicate that optimizing the crop planting structure can improve crop yields and provide reference for decision-makers in crop planting planning and market pricing.
Keywords: Crop planting structure; Linear programming; Monte carlo method; Heat map correlation

1 INTRODUCTION

Ling Qiu County, Datong City, Shanxi Province, China has 12 townships and 186 administrative villages, with a total population of 250000, including 200000 agricultural population. Since 2013, the county has formulated the "Implementation Plan for Organic Agriculture Park in Lingqiu County (2013-2030)". After nearly 11 years of development, its total organic agriculture output value has reached 580 million yuan, and it has built the largest contiguous organic agriculture park in China. In addition, Lingqiu County has been selected as a "Shanxi Province Agricultural Product Quality and Safety Demonstration Creation Unit", and Hongshileng Township has also been rated as a "China Organic Agriculture Development Demonstration Township". The area attaches great importance to soil improvement and protection, and through research on crop planting structure and scientific and reasonable farming methods, it has laid the foundation for the sustainability of organic agriculture.

Therefore, reasonable planning of crop planting structure plays an important role in regional crop income. At present, scholars at home and abroad have conducted research on crop planting structure. Hu M et al[1] optimized the crop planting structure in Heilongjiang Province through multi-objective interval parameter planning and other methods. The results showed that slope, population density, and average temperature in the coldest season were the main factors affecting the distribution of rice, corn, and soybeans. Liu Q et al[2] established a multi-objective spatial CPSO model and conducted a case study on the middle and upper reaches of the Heihe River Basin in Gansu Province, China. The optimization of planting structure significantly improved regional water resources and ecological benefits at different scales, Adamo T et al[3] solved the intercropping system in crop planting structure based on constraint programming models of integer and interval variables. Alotaibi A et al[4] analyzed the application of feed mixing, crop patterns and rotation plans, irrigation water and product conversion through linear programming models. Adeyemo J et al[5] applied differential evolution algorithm (DE) and linear programming model (LP) to optimize planting area and maximize the use of irrigation water. Li M et al[6] conducted multidimensional optimization of AWLR (Water Resources, Land Resources, and Sustainable Development) by establishing a framework model that combines multiple models such as multi-objective programming and linear programming. Abdelwahab et al[7] studied the planting patterns in the eastern delta region, especially in the areas supplied by the Ismailia Canal, by establishing a linear programming model to solve the problem of balancing limited freshwater supply. Reddy D J et al[8] used machine learning (ML) to estimate crop yield based on weather conditions. Luo N et al[9] analyzed data from 87 field experiments in China by combining data-driven prediction with machine learning methods, and concluded that by optimizing the dense planting structure of crops, China's corn yield will increase by 52% by the 2030s. Gebre et al[10] conducted a systematic literature review of 69 articles on Multi Criteria Decision Making (MCDM) and found that Linear Programming (LP) and Simulated Annealing (SA) methods are mainly used for optimizing multi-objective complex agricultural and forest land allocation problems.

Most scholars have analyzed the crop planting structure of the block area through mathematical models, and made current and future characteristics and trends of crop planting structure in the area, or analyzed a single constraint condition in the crop planting structure. However, they rarely combine multiple constraints of crop planting structure and apply them to the problem of crop planting income.

The spatial structure of crop planting mainly includes the planting area, planting yield, and planting ratio of different crops, while the temporal structure of crops mainly includes multiple constraints such as land rotation system, climate, crop spacing, and land use mode. The linear programming model, as an efficient mathematical model, is widely used in dealing with large-scale problems and can effectively handle a series of constraints. At the same time, for some unpredictable factors in the time structure, Monte Carlo simulation can be used to simulate unpredictable factors such as climate and market fluctuations in prices.

Therefore, based on the planting situation in Xiahe Village, Lingqiu County, Datong City, Shanxi Province in 2023, this article analyzes and optimizes the planting structure of its crops, and presents the planting situation from 2023 to 2030. By constructing a maximum profit objective function and combining linear programming and Monte Carlo methods to optimize crop planting structure, a correlation analysis was conducted on the sales cost, sales price, and yield per mu of crops in Xiahe Village in 2023.

This article combines multiple constraints in crop planting structure, such as rotation system, planting density, market fluctuations, etc., and conducts comprehensive optimization through linear programming and Monte Carlo methods. This comprehensive treatment of multiple constraint conditions provides decision-makers with a more comprehensive planting planning scheme, which can effectively improve the economic benefits of crop planting. At the same time, the Monte Carlo method was used to simulate unpredictable factors such as market volatility and climate change, enhancing the robustness and practicality of the model. This method not only helps decision-makers better cope with uncertainty, but also provides new ideas for risk management in agricultural planting.

2 APPLICATION METHOD DESCRIPTION

2.1 Linear Programming Model

The linear programming model was proposed by George Dantzig[11]. It gradually improves the solution through iteration until the optimal solution is found, which is applicable to most practical problems, but due to its own limitations, it cannot solve nonlinear problems. This model mainly consists of decision variables, objective functions, and constraint conditions.

2.1.1 Decision variables

The decision variables in linear programming models are the unknowns that need to be solved, usually represented by $x_1, x_2, \ldots, x_n$. For example, the production quantity of each production level in the production plan.

2.1.2 Objective function

The objective function in linear programming is the function that needs to be maximized or minimized, and its general form is:

$$\text{Maximize(or Minimize)} \quad Z = c_1x_1 + c_2x_2 + \ldots + c_nx_n \tag{1}$$

Among them c_1、$c_2, \ldots, c_n$ are coefficients representing the contribution of each variable in the objective function.

2.1.3 Constraints

Linear inequalities or equations that limit the values of decision variables.

General form:

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n \le b_1 \\ a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n \ge b_2 \\ \ldots \\ a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n \le b_m \end{aligned} \tag{2}$$

Among them, a_{ij} is a coefficient and b_{ij} is a constant.

2.2 Monte Carlo Method

Monte Carlo simulation is a statistical sampling method used to evaluate solutions to quantitative problems[12]. Its theoretical basis is the law of large numbers and the central limit theorem, and one of its core ideas is to randomly select points from a certain range, and then approximate the problem through the statistical properties of these random points. For example, calculating area, calculating pi, etc. The most typical example is to randomly replace a square with a side length of 2, and then calculate the proportion of points falling into the inscribed circle. Based on this proportion, the pi can be obtained.

This article sets the probabilities of some unpredictable factors and uses Monte Carlo method to select a random value for each probability to repeatedly simulate the model, thereby achieving the randomness of unpredictable factors.

3 DATA ANALYSIS AND VISUALIZATION

Xia Che He Village contains 1216 acres of arable land, consisting of 6 land types divided into 34 plots, including flat dry land, terraced fields, hillside land, and irrigated land. These lands are suitable for growing different crops such as grains, rice, and vegetables. In addition, the village also has 16 standard greenhouses and 4 smart greenhouses, suitable for growing vegetables and edible fungi. (Data source: Shanxi Statistical Yearbook) Different crops have different planting costs, yields per mu, and sales unit prices on different land types, and some crops can only be planted on specific types of land.

3.1 Comparison of Economic Benefits of Six Land Types

Table 1 Land Area

Flat dry land(mu)	Terraced Fields(mu)	Hillside land(mu)	Irrigated land(mu)	Ordinary greenhouse(mu)	Smart greenhouse(mu)
365	619	108	109	9.6	5.4

Table 1 shows the land area of six land types. Although the crop planting cost and yield per mu of the latter three land types are higher than the first three, their planting area is lower. Here, this paper can discuss the economic benefits of each type of land to intuitively reflect which type of land would yield more ideal income from planting crops. Thus providing reference for the results of linear programming models.

The box plot provides a visual representation of the distribution and median of planting costs, yield per mu, and sales unit price for different crops in the six land types. Generally, total profit = revenue − cost, where in this article, revenue=yield per mu x sowing area x sales unit price. Here, this paper use the median in the box plot as the planting cost, yield per mu, and sales unit price for each plot type to roughly calculate and compare the economic benefits of the six land types.

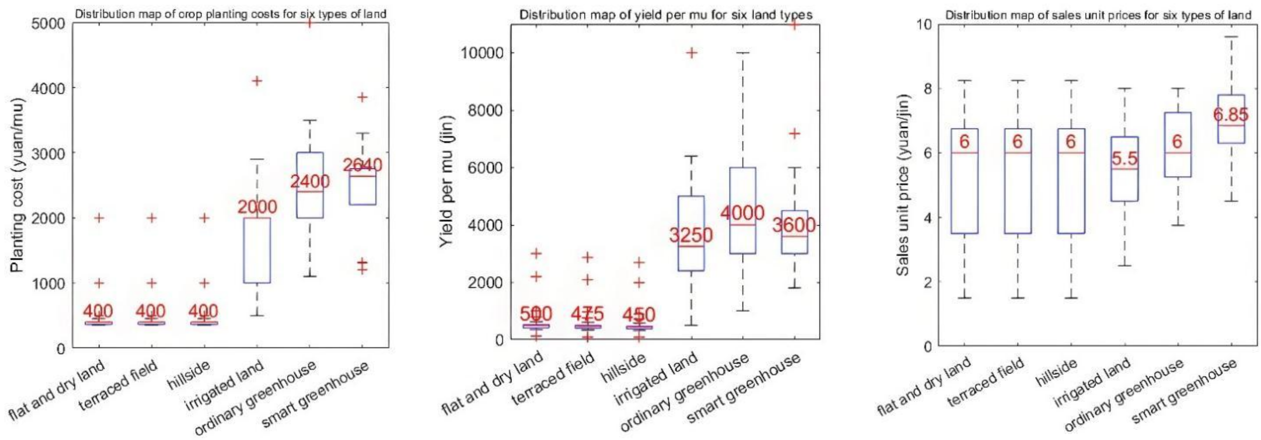

Figure 1 Distribution of Crop Planting Costs, Yield Per Mu, and Sales Unit Price among Six Land Types

According to the distribution chart of crop planting cost, yield per mu, and sales unit price among six land types in Figure 1, it suggests that the cost of smart greenhouses and ordinary greenhouses is higher in planting cost, while the planting cost of flat land, terraced fields, and mountainous areas is lower. In terms of yield per mu, irrigated land, ordinary greenhouses, and smart greenhouses have higher yields, while flat land, terraced fields, and mountainous areas have lower yields per mu. The price of smart greenhouses is higher in the sales unit price.

At the same time, this paper calculates the economic benefits of each land type by obtaining the median of planting costs, yield per mu, and sales unit price for the six land types.

Table 2 Total Profit of Six Land Types

Flat dry land(yuan)	Terraced Fields(yuan)	Hillside land(yuan)	Irrigated land(yuan)	Ordinary greenhouse(yuan)	Smart greenhouse(yuan)
949000	1516550	248400	1730375	207360	118908

According to Table 2, the total profit of the six land types shows that irrigated land has the highest economic benefits, while smart greenhouses have the lowest economic benefits. At the same time, this paper studies the correlation between the planting cost, yield per mu, and sales unit price data of crops, providing reference for decision-makers to set sales unit prices and choose crops to plant.

3.2 Correlation Analysis of Crop Planting Cost, Yield Per Mu, and Sales Unit Price

In the actual production process, total profit is related to sales price, sales cost, and yield per mu. This paper considers using Pearson correlation coefficient r to verify the internal relationship between the three. Obtain the Pearson correlation coefficient heatmap of matrices C_{ij},P_{ij} and R_{ij} in Figure 2.

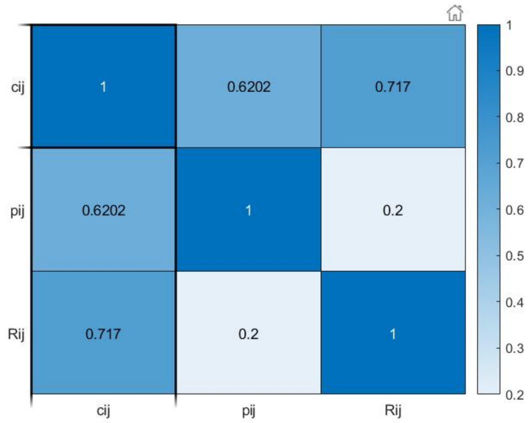

Figure 2 Pearson correlation coefficient heatmap of matrices C_{ij},P_{ij} and R_{ij}

Finally, the correlation coefficient between C_{ij} and P_{ij} is 0.620, the correlation coefficient between C_{ij} and R_{ij} is 0.717, and the correlation coefficient between P_{ij} and R_{ij} is 0.2.

That is to say, there is a strong correlation between sales cost, sales unit price, and yield per mu. The sales unit price has a strong correlation with sales costs and a weak correlation with yield per mu. The yield per mu is strongly correlated with sales costs, but weakly correlated with sales unit prices.

When pursuing maximum profits in practice, this model needs to consider the relationship between sales unit price, sales cost, and yield per mu, rather than solely relying on the maximum or minimum value of a variable to determine how to plant a certain crop on a certain plot of land.

Based on the above data analysis, the first constraint this paper needs to determine is that different plots require different types of crops to be planted, and the planting costs, yield per mu, and sales unit price of some crops planted on different plots are also different. At the same time, it is necessary to consider the correlation between these three factors when constructing the model.

4 CONSTRUCTION OF LINEAR PROGRAMMING MODEL

4.1 Determination of Constraints on Crop Planting Structure

The optimization of crop planting structure includes multiple constraints such as variety selection, rotation system, and planting density. Based on the planting situation, soil conditions, and natural conditions in Xiahe Village in 2023, a linear programming model is constructed by considering crop rotation system, planting density, planting area of various crops, and market fluctuations as the main constraints, and establishing the objective function of maximizing income. The maximization of income under the optimization of crop planting structure is discussed.

4.1.1 Crop rotation system

According to the growth pattern of crops, each planting process absorbs trace elements from the soil, resulting in an imbalance of trace elements in the soil. Therefore, each crop cannot be continuously planted in the same plot (including greenhouses), otherwise it will reduce production. At the same time, intercropping can promote the absorption of phosphorus by crops and increase the content of phosphorus in the soil[13]. For example, the phosphorus produced by legume crops can be used as a nitrogen source in the soil, which is beneficial for the growth of other crops. Moreover, the mixed planting of legumes and grasses is highly valued in many parts of the world for its advantages of increasing yield, reducing soil erosion, and minimizing pests and diseases. So it is possible to plant legumes as much as possible during the crop planting process, which is beneficial for the economic benefits of crops. However, it should also be noted that leguminous crops cannot be planted continuously[14].

Due to the varying drainage and soil fertility indices of different food crops, implementing a rotation planting plan is necessary to avoid soil nutrient imbalance caused by long-term planting of a single crop, disrupt the growth and activity space of pests and diseases, and ensure the healthy growth of crops[15].

4.1.2 Planting area

At the same time, the planting plan should take into account the convenience of farming operations and field management. The planting areas for each crop per season should not be too scattered, and the planting area for each crop on a single plot (including greenhouses) should not be too small. Moreover, crops often need to be planted under certain temperature, humidity, and light conditions, but different crops have certain differences in the above indicators, and the sowing time is also different. Therefore, the cost of planting different crops on different land types varies, and their selling prices are also different. Therefore, it is necessary to choose a suitable planting area to achieve maximum profits.

4.1.3 Market volatility

Under market fluctuations, crop prices are influenced by numerous factors, such as seasonal fluctuations in vegetable prices caused by the production of different varieties of vegetables, inflation affecting crop price fluctuations, and the impact of external factors on agricultural product market fluctuations. For example, higher agricultural inflation may disrupt stability through lower output and higher overall inflation[16].

Therefore, under ideal conditions where market volatility tends to be relatively stable, this model can simulate small fluctuations in market volatility by selectively increasing our variables such as expected sales volume, planting cost, yield per mu, and sales price through Monte Carlo analysis. At the same time, this paper introduces market volatility to simulate other factors that affect market volatility, such as inflation.

4.1.4 The replaceability and complementarity of crops

There may be certain substitutability and complementarity between various crops in the market. For substitutability and complementarity, this paper can introduce substitutability coefficient and complementarity coefficient to quantify the relationship between the two crops. Finally, the optimal solution can be obtained by using linear programming.

4.1.5 Expected sales volume

This paper sets the expected sales volume for each crop based on the planting plan for the 2023 vehicle and village crops, and treat it as unsold waste if it exceeds the expected sales volume.

4.2 Symbol Explanation and Model Assumptions

Table 3 Symbol Explanation

Symbol	Explanation
$\boldsymbol{X_{ijt}}$	*The planting area of crop i in season t on land j*
C_{ij}	*The cost of crops on j plots of land*
P_{ij}	*The selling price of crop i on land j*
S_i	*Expected sales volume of crop i*
α	Minimum planting restriction coefficient
β	Penalty Coefficient
R_{ij}	Indicate the yield per mu of crop i on land j
δ_{kT}	Indicate the increase or decrease rate of the k-th option in the T-th year
Q_{ijt}	Indicate the yield of crop i on land j in the t-th quarter
B_{jt}	Indicate the area of j land in quarter t

According to Table 3, it is easy to understand the meaning of the formulas in the following text. For the impact of market fluctuations and other factors on crops, this chapter plans to optimize the crop planting structure for 7 years, and adjust the range of expected sales volume, planting costs, yield per mu, and sales price fluctuations annually.

Expected sales volume: The annual growth rate of wheat and corn ranges from 5% to 10%, while the expected sales volume of other crops fluctuates by ± 5% relative to 2023.

Planting cost: All crops increase by approximately ± 5% annually.

Mu yield: The annual mu yield of all crops may fluctuate by ± 10%.

Sales price: The prices of grain crops are basically stable. For vegetable crops, the sales unit price increases by about 5% annually, while the sales unit price of edible mushrooms decreases by 1% to 5% annually, especially the sales unit price of morel mushrooms decreases by 5% annually.

4.3 Establishment of Objective Function and Constraint Conditions

4.3.1 Objective function

$$\sum_{t=1}^{14}\sum_{j=1}^{54}\sum_{i=1}^{41} P_{ij}\times R_{ij}\times X_{ijt} - C_{ij}\times X_{ijt} \tag{3}$$

Among them, i, j, and t are all integers (the same applies in the following text)

4.3.2 Constraints

1. The planting area of each crop cannot exceed the area on that land.

$$\sum_{t=1}^{14}\sum_{j=1}^{54}\sum_{i=1}^{41} X_{ijt} \le B_{jt} \tag{4}$$

Among them, B_{jt} represents the area of the j-th piece of land in the t-th quarter

2. Grain crops can only be planted in flat dry land, terraced fields, and mountain slopes, except for rice. Vegetable crops can be planted in irrigated land and two types of greenhouses, while edible fungi can only be planted in ordinary greenhouses.

In flat land, terraced fields, and hillside areas, there are:

$$\sum_{i=16}^{41} X_{ijt} = 0\,, \mathrm{j} \in [1,26], \mathrm{t} \in [1,14] \tag{5}$$

In irrigated land, there are:

In the first quarter of irrigated land, only crops with $i \in [17,34]$ can be planted, and in the second quarter, only crops with $i \in [35,37]$ can be planted.

$$\sum_{i=1}^{16} X_{ijt} + \sum_{i=38}^{41} X_{ijt} = 0, j \in [27,34], t \in [1,14] \tag{6}$$

$$\sum_{i=35}^{37} X_{ijt} = 0, j \in [27,34], t \in \{1,3,\ldots,11\} \tag{7}$$

$$\sum_{i=17}^{34} X_{ijt} = 0, j \in [27,34], t \in \{2,4,\ldots,14\} \tag{8}$$

In ordinary greenhouses, there are:
In ordinary greenhouses, only crops from 17 to 34 can be selected for planting in the first season, and only crops from 38 to 41 can be selected for planting in the second season.

$$\sum_{i=1}^{16} X_{ijt} + \sum_{i=35}^{37} X_{ijt} = 0, j \in [35,50], t \in [1,14] \tag{9}$$

$$\sum_{i=38}^{41} X_{ijt} = 0, j \in [27,34], t \in \{1,3,\ldots,11\} \tag{10}$$

$$\sum_{i=17}^{34} X_{ijt} = 0, j \in [27,34], t \in \{2,4,\ldots,14\} \tag{11}$$

In the smart greenhouse, there are:
The smart greenhouse can plant two seasons of vegetables every year (excluding Chinese cabbage, white radish, and red radish). Moreover, Chinese cabbage, white radish, and red radish can only be planted in the second season.

$$\sum_{i=1}^{16} X_{ijt} + \sum_{i=38}^{41} X_{ijt} = 0, j \in [51,54], t \in [1,14] \tag{12}$$

$$\sum_{i=35}^{37} X_{ijt} = 0, j \in [51,54], t \in \{1,3,\ldots,11\} \tag{13}$$

3. Leguminous crops must be planted every three years.

$$\sum_{t=1}^{6}\sum_{i=1}^{5} X_{ijt} + \sum_{t=1}^{6}\sum_{i=17}^{19} X_{ijt} \geq 1, \forall j \tag{14}$$

$$\sum_{t=6}^{12}\sum_{i=1}^{5} X_{ijt} + \sum_{t=6}^{12}\sum_{i=17}^{19} X_{ijt} \geq 1, \forall j \tag{15}$$

4. Crop management requires that the planting area of crops should not be too small (Planting area).

$$X_{ijt} \geq \alpha, \forall i,j,t \tag{16}$$

Among them, α is the minimum limit constant for planting area.
5. Market fluctuations
We use Monte Carlo method to simulate the changes in market volatility within the following range of variation There is a growth trend of 5% to 10% for wheat and corn. Other crops have a growth trend of ± 5%. The sales unit price of grain crops is basically stable, while the sales unit price of vegetable crops has a growth trend of 5%. Edible mushrooms decrease by about 1% to 5% annually, with morel mushrooms decreasing by 5%. The yield per mu of all crops varies by ± 10% annually. The planting cost of all crops increases by 5% annually.
Changes in expected sales volume, unit price, yield per mu, and planting cost on the original data. It can be divided into the following 7 schemes.
(1) The expected sales volume of wheat and corn is:

$$S_i \times (1+\delta) = S_i^{'}, i = 6,7, \delta \epsilon [0.05,0.10] \tag{17}$$

(2) The expected sales volume of other crops is:

$$S_i \times (1+\delta) = S_i^{'}, i \neq 6,7, \delta \epsilon [-0.05,0.05] \tag{18}$$

(3) Sales unit price of grain crops:

$$P_{ij} = P_{ij}^{'}, i = [1,16] \tag{19}$$

(4) Sales unit price of vegetable crops:

$$P_{ij} \times (1+\delta) = P_{ij}^{'}, i = [17,37], \delta \epsilon [0,0.05] \tag{20}$$

(5) Sales unit price of edible mushrooms:

$$P_{ij} \times (1+\delta) = P_{ij}^{'}, i = [38,40], \delta \epsilon [-0.05,-0.01] \tag{21}$$

$$P_{ij} \times (1+\delta) = P_{ij}^{'}, i = 41, \delta = -0.05 \tag{22}$$

(6) The yield per mu of all crops:

$$R_{ij} \times (1+\delta) = R_{ij}^{'}, \forall i, \delta \epsilon [-0.1,0.1] \tag{23}$$

(7) The planting cost of all crops:

$$C_{ij} \times (1+\delta) = C_{ij}', \forall i, \delta \epsilon [0,0.05] \quad (24)$$

For cases (1)~(7), take random numbers of δ within the range of δ for each case, because there are a total of 7 years, so each case needs to take 7 random numbers to achieve the impact of unpredictable factors on the planting plan. The value of δ for the kth scheme in the Tth year is denoted as δ_{kT}.

Among them, $k = [1,7], T = [1,7]$.

6. The complementarity and substitutability of crops

Complementarity explains the mutual influence between different crops, and this paper set a complementarity coefficient to measure the complementarity between two different crops.

$$Q_{ijt} = X_{ijt} \times R_{ij} \times (1 + \sum_{k=1}^{41} \omega_{ik} \times Q_{kjt}) \quad (25)$$

Among them: ω_{ik}, Indicating the complementary strength of the ith crop to the kth crop, that is, planting the ith crop will increase the yield of the kth crop. Q_{ijt} represents the yield of the i-th crop in the jth quarter of the jth plot of land. Yield=planting area × yield per mu.

The substitutability indicates that the two crops have an opposite relationship, that is, an increase in crop i's yield will result in a decrease in crop k. This paper uses substitution coefficients to measure this relationship.

$$Q_{ijt} = X_{ijt} \times R_{ij} \times (1 + \sum_{k=1}^{41} \theta_{ik} \times Q_{kjt}) \quad (26)$$

Among them, θ_{ik} represents the substitution coefficient between the ith crop and the kth crop, and the stronger the coefficient, the more the kth crop reduces the yield of i.

7. Market price fluctuations

Our net income is determined by market volatility and selling price, when the market volatility is τ. So our earnings are:

$$P_{ij} \times \min(Q_{ijt}, S_i) \times (1+\tau) \quad (27)$$

Among them, min (Q_{ijt}, S_i) represents our handling of unsold and wasteful excess parts, and τ is the market volatility.

4.4 Experimental Results and Discussion

Through the correlation analysis of crop planting structure, yield per mu, and sales unit price, this paper finally has obtained the Pearson correlation coefficient of the three as shown in the Table 4 below.

Table 4 Correlation coefficients between planting cost, yield per mu, and sales unit price.

C_{ij} and R_{ij}	C_{ij} and P_{ij}	R_{ij} and R_{ij}
0.717	0.620	0.200

By constructing a linear programming model and Monte Carlo method to simulate unpredictable factors, and analyzing the constraints of crop planting structure on crop planting area, rotation system, crop selection, market fluctuations, weather prediction, and legume rotation, as well as constructing objective functions, a linear programming model was obtained, resulting in a total profit of 270 million yuan after 7 years of simulation.

The use of linear programming models and Monte Carlo methods to solve such problems provides methods and references for decision-makers in actual production processes. Simultaneously using Monte Carlo method to quantitatively analyze some unpredictable factors can effectively avoid the risks that may lead to reduced returns in the actual production process, as well as other related risks. In the correlation analysis, the correlation between crop planting cost, yield per mu, and sales unit price was also explained, among which planting cost and yield per mu, planting cost and sales unit price have a strong correlation.

5 CONCLUSION AND IMPLICATIONS

With the increasing demand for sustainable agricultural development, reasonable crop planting strategies are crucial for improving production efficiency, reducing planting risks, and achieving efficient resource utilization.

Starting from the issue of crop planting structure, this article conducted data analysis and visualization on 54 plots of 41 crops and 6 types of land. Research has found that different crops require different restrictions to be planted on different lands. At the same time, constraints such as planting legumes and crop rotation in actual production were added to the model to make it more realistic. Then, through model assumptions, the range of market volatility was set. Finally, construct the objective function and constraints of linear programming to obtain the final yield of 7-year planting.

The crop planting structure optimization model based on linear programming and Monte Carlo method proposed in this article has strong application feasibility and wide applicability. This model can effectively help decision-makers optimize the planting structure and improve the economic benefits of crop planting by comprehensively considering multiple constraints such as planting costs, yield per mu, and sales prices. Especially in rural areas of China, this model can provide farmers with scientific planting planning, reduce planting risks, and improve land use efficiency. In addition, the model also simulated unpredictable factors such as market volatility and climate change through Monte Carlo method, enhancing the robustness and practicality of the model.

Future research directions can further expand the applicability of the model, such as introducing nonlinear programming methods to address more complex agricultural problems, or combining big data and artificial intelligence technologies to adjust planting strategies in real time. In addition, the model can consider more environmental factors such as natural disasters, pests and diseases to improve the accuracy of predictions. Finally, the model can also be applied to other agricultural fields such as animal husbandry, fisheries, etc., further promoting the sustainable development of agriculture.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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