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Research on the Optimal Profit of Planting Schemes Based on 0-1 Programming Model

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Abstract: *This paper focuses on the limited arable land resources in a rural area of the mountainous region in North China, studying the planting schemes of crops and calculating the maximum profit. Based on the planting and sales situation in 2023, this paper is divided into two categories: the price and sales situation of each crop in the future remain stable as in 2023; and considering market changes and yield changes to study the maximum profit of crop planting from 2024 to 2030. By establishing a 0-1 programming model and using Monte Carlo simulation to predict the total output of various crops from 2024 to 2030, the profit of this planting scheme is calculated under the premise of maximizing the profit of each year's planting scheme. Through simulation, the annual economic benefit is more than 20 million yuan. This study can not only provide scientific decision support for crop cultivation in rural mountainous areas of North China, but also provide theoretical reference for agricultural resource allocation in other similar areas.*

Keywords: *0-1 Planning Model, Planting Scheme, Maximum Yield, Monte Carlo Simulation*

1. Introduction

As the basic industry of the national economy, whether the production efficiency and the utilization rate of planting land are reasonable directly affects the national grain production and farmers' income level. In recent years, China's agricultural modernization has been accelerating, and how to achieve the optimal allocation of crop planting under the limited cultivated land area has become an important research topic in the field of agricultural economics and management. The per capita water resources and the allocation ratio of water and soil resources in North China are lower than the national average level, but it is an important grain production base in China[1-2].

At present, researchers at home and abroad have carried out a lot of research on crop planting optimization. Traditional research methods are mostly based on linear programming[3]or dynamic programming[4], or focusing on a single objective, such as maximizing revenue or minimizing costs[5], or consider only rotation requirements[6][7],However, multiple constraints, such as land resource constraints and market demand fluctuations, are often considered in actual agricultural production, which makes it difficult for a single objective optimization model to fully reflect the complex reality.

In view of the above problems, this paper takes a village in the mountainous area of North China as the research object, combines 0-1 programming model, Monte Carlo simulation and robust optimization method, and proposes a crop planting optimization strategy that comprehensively considers the maximization of income, rational utilization of resources and income balance. The main innovation of the research is that the 0-1 programming model is introduced to transform the planting decision problem into a discrete optimization problem, which can more accurately describe the choice behavior in actual planting and use Monte Carlo simulation method to simulate the planting scheme under different environmental conditions to calculate the annual income.

The results of this study can not only provide scientific decision support for crop cultivation in rural mountainous areas of North China, but also provide theoretical reference for agricultural resource allocation in other similar areas. At the same time, the comprehensive optimization method proposed in this paper can be used to other fields of resource allocation problems, and has a wide range of application value.

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2. Research on planting scheme based on 0-1 planning model

This paper assumes that the expected future sales volume, planting cost, yield per mu and selling price of various crops will remain stable relative to 2023; The expected sales volume in 2024 to 2030 equals the actual production in 2023. The 0-1 programming model is used to solve the problem. By setting the decision variables, the objective function and the constraint conditions of the objective function, the objective function is solved. By comparison, the planting plan for maximizing the income from 2024 to 2030 is obtained.

But in practice, farmers tend to grow more profitable crops[8],as a result, when a large number of farmers follow the trend of planting the same crop, the market is oversupplied, resulting in lower prices and thus lower profits. As profits fall, fewer people grow the crop, supply and demand gradually return to balance, and profits rise again, and so on. Therefore, the optimal planting decision should take into account the maximization of planting income and the small fluctuation of per capita income difference. However, this constraint cannot be achieved in this paper, so the planting scheme that maximizes revenue is regarded as the optimal planting decision in this paper.

2.1 Set decision variables

The following decision variables are defined:Suppose that in quarter j of year t. The area planted with crops on plot i is $S_{i,j,t}$; In season j of year t,The type of crop planted on the i plot is $X_{i,j,t}$. Where, i represents the number of each plot,t is for different years, S stands for different crop types, X represents the type of crop cultivated.

This paper aims to calculate the income of the village under the optimal planting scheme from 2024 to 2030, that is, to solve the income under the optimal planting simulation. According to the sales and production of crops in the village in 2023 as the basic data, the crop output in 2023 is taken as the expected sales volume. When the actual crop output is lower than the expected output, no waste will be generated, while when the crop output is higher than the expected output, The part exceeding the expected output will be wasted and the part exceeding the expected output will be sold at half price.

2.2 Constraints

(1) Plot area constraint: the total area of crops planted in each plot shall not exceed its actual area, that is.

$$\sum_{X_{i,j,t}} S_{i,j,t} \leq K_{i,j,t} \forall i,j \tag{1}$$

(2) Constraint that legume crops must be planted once within three years: legume crops must be planted at least once every three years in each plot [9][10], namely:

$$\sum_{Within\ 3\ years} \sum_{X_{i,j,t \in beans}} S_{i,j,t} \geq 1 \forall i \tag{2}$$

(3) Non-re-cropping constraint: it is required that the same crop cannot be planted in each plot every year [11], namely:

$$X_{i,j,t} \neq X_{i,j,t+1} \forall i,j,t \tag{3}$$

(4) Constraints on crop planting conditions: only food crops can be grown in flat and dry land, terraces and mountain slopes; rice or two-season vegetables can be grown in irrigated land; vegetables and edible fungi can be grown in greenhouses, namely:

$$S_{i,j,t}=0, \text{The plot type is not suitable for crop j} \tag{4}$$

(5) Fungus crops can only be grown in the second season of the ordinary greenhouse:

$$X_{j=1} \neq X_{fungi}; X_{j=2} = X_{fungi}; i_{d \leq 16}, \forall d \tag{5}$$

(6) Greenhouse area constraint: the area of each greenhouse is fixed, and the planting area cannot exceed 0.6 mu.

(7) Cultivated land area constraint:

$$\sum_{X_{i,j,t}} S_{i,j,t} \leq 1201 \forall t \tag{6}$$

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2.3 Solution of unsalable part of overproduction

The income of each crop in year t can be expressed as:

$$Y_{X_{i,j,k}} min\left(M_{X_{i,j,t}} * S_{i,j,t}, A_{X_{i,j,t}}\right) - \sum_i \sum_j \sum_t B_{S_{i,j,t}} \times X_{i,j,t} \quad (7)$$

The objective function of total revenue can be expressed as:

$$W = \sum_{t=2024}^{2023} \sum_{i=1}^{34} \sum_{j=1}^{M} Y_{X_{i,j,k}} min\left(M_{X_{i,j,t}} * S_{i,j,t}, A_{X_{i,j,t}}\right) - \sum_i \sum_j \sum_t B_{S_{i,j,t}} \times X_{i,j,t} \quad (8)$$

Among them:$X_{i,j,t}$denotes the type of crop cultivated;$Y_{X_{i,j,k}}$ is the selling price of crop $X_{i,j,t}$; $M_{X_{i,j,t}}$ denotes the yield per mu of crop $X_{i,j,t}$.μ represents the discount rate at which the actual crop yield exceeds the expected yield (μ=0 when the expected yield is equal to the actual yield, that is, case 1, μ=1 when the actual yield is greater than the expected yield, that is, case 2).

By establishing a 0-1 planning model, the optimal planting scheme from 2024 to 2030 is optimized according to the constraints mentioned above in this paper, and the scheme is calculated and solved.

2.4 Solution of half-price sales for overproduction

The solution of this situation is similar to that of the unsalable part of the overproduction, except that the part exceeding the expected output is treated differently, and the excess part no longer produces waste. In this case, the part exceeding the expected yield is sold at a 50% price reduction, but the ultimate goal remains unchanged, always requiring that the ultimate benefit of the planting scheme be maximized.

The difference between the overproduction part and the unsalable overproduction part lies only in the revenue of the overproduction part, so the objective function needs to add the revenue of the overproduction part to the overproduction part.

When the yield of crop j may be less than or equal to the expected yield, or greater than the expected yield, combined with the planting cost, the yield of a single crop can be expressed as:

$$Y_{X_{i,j,k}} min\left(M_{X_{i,j,t}} \times S_{i,j,t}, A_{X_{i,j,t}}\right) + \mu Y_{X_{i,j,k}} \times max\{M_{X_{i,j,t}} \times S_{i,j,t} - A_{X_{i,j,t}}, 0\} - \sum_i \sum_j \sum_t B_{S_{i,j,t}} \times X_{i,j,t} \quad (9)$$

Then the total objective function of crop income is obtained:

$$W = \sum_{t=2024}^{2023} \sum_{i=1}^{34} \sum_{j=1}^{M} Y_{X_{i,j,k}} min\left(M_{X_{i,j,t}} \times S_{i,j,t}, A_{X_{i,j,t}}\right) + \mu Y_{X_{i,j,k}} * \max\{M_{X_{i,j,t}} * S_{i,j,t} - A_{X_{i,j,t}}, 0\} - \sum_i \sum_j \sum_t B_{S_{i,j,t}} \times X_{i,j,t} \quad (10)$$

Among them: $X_{i,j,t}$ denotes the type of crop cultivated; $Y_{X_{i,j,k}}$ denotes the selling price of crop $X_{i,j,t}$; $M_{X_{i,j,t}}$M denotes the yield per mu of crop $X_{i,j,t}$.μ represents the discount rate at which the actual crop yield exceeds the expected yield (μ=0 when the expected yield is equal to the actual yield, that is, case 1, μ=1 when the actual yield is greater than the expected yield, that is, case 2).

Through the establishment of 0-1 planning model, the optimal planting scheme from 2024 to 2030 is optimized according to the constraints mentioned above in this paper, and the scheme is calculated and solved.

The annual profits according to Scheme 1 and Scheme 2 are visualized as shown in Figure 1:

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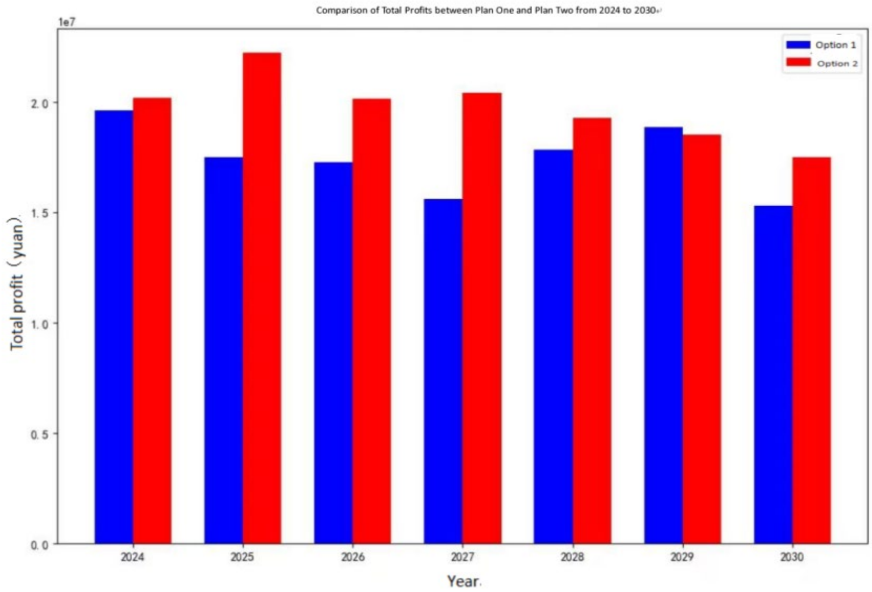

Fig.1 Comparison of the total benefits of the two schemes

3. Research on the benefits of optimal planting scheme under multiple factors based on 0-1 programming model

3.1 Establishment of the model

It is necessary to consider the uncertainty of sales price and potential planting risks during the planting period on the basis of the expected sales volume, yield per mu, planting cost and sales price of crops. In addition, the expected sales volume, yield per mu, planting cost and sales price all fluctuate and are uncertain values. In this case, the optimal planting plan for the village from 2024 to 2030 should be formulated.

In order to solve the uncertainty and risk, Monte Carlo simulation and robust optimization models are used in this paper.

Monte Carlo simulation

Monte Carlo simulation simulates the uncertainty of planting and selling process by repeating random sampling in the range of expected sales volume, yield per mu, planting cost and selling price. By randomly drawing samples, different scenarios are generated to make decision analysis of this problem.

Uncertainties: the impact of climate factors on yield per mu, fluctuations in planting costs, changes in selling prices.

Expected sales: Average annual growth for wheat and corn is between 5 and 10 percent, with projected future sales for other crops changing by approximately ±5 percent per year relative to 2023.

Yield per mu: subject to ±10% annual variation due to climate and other factors.

Cost changes: The cost of growing crops has increased by about 5% per year on average due to market conditions.

Changes in selling prices: the selling prices of grain crops are basically stable; The selling price of vegetable crops increases by about 5% per year on average. The sales price of edible fungi can be reduced by about 1% to 5% per year, and the sales price of morels can be reduced by 5% per year.

3.2 Establish the objective function and solve it

In this paper, the returns from 2024 to 2030 are still maximized under multiple uncertain conditions. Different from the situation discussed above, the sales volume, output per mu, cost and selling price in this problem are random variables rather than fixed values.

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Monte Carlo simulations were used to generate uncertainty scenarios for future crop cultivation.

Finally, the objective function of the total revenue from 2024 to 2030 can be obtained:

$$W = max \sum_{t=2024}^{2030} \sum_X \left(M_{X_{i,j,t}} \times S_{X_{i,j,y}} \times Y_{X_{i,j,t}} - S_{X_{i,j,t}} \times B_{X_{i,j,t}}\right) \tag{11}$$

Among them:$M_{X_{i,j,t}}$ represents the yield per mu of crop X planted in year t.,$S_{X_{i,j,y}}$ represents the planted area of crop X in year t.$Y_{X_{i,j,t}}$ denotes the selling price of crop X grown in year t.$B_{X_{i,j,t}}$ denotes the planting cost of planting crop X in year t.

Through the establishment of 0-1 planning model, the optimal planting scheme from 2024 to 2030 is optimized according to the constraints mentioned above in this paper, and the scheme is calculated and solved. The income for each of the years from 2024 to 2030 is: the total profit in 2024 is: RMB23,669,969.5, the total profit in 2025 is: RMB23,685,194.4, the total profit in 2026 is: RMB23,182,176.10, the total profit in 2027 is: Rmb24,608,628.07, the total profit for the year 2028: RMB23,417,694.98, the total profit for the year 2029: RMB22,880,506.12 and the total profit for the year 2030: RMB2,497,800.23. This scheme considers that the market change is more applicable to the real life crop sales situation.

4. Conclusions

Aiming at the limited cultivated land resources of a village in the mountainous area of North China, this paper uses 0-1 programming model to study the income of selling the overproduction part at half price and the unsalable income of the overproduction part, and obtains the income under two conditions. On this basis, Monte Carlo simulation and robust optimization are used to obtain the optimal planting scheme under the influence of various uncertain factors in the market environment, which takes into account the market changes and is more suitable for the sales of crops in real life.

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