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THE CROP PLANTING PROBLEM BASED ON THE OPTIMIZATION MODEL

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Abstract: The development of modern agricultural technology and the limited cultivated land planting resources in China make people pay more attention to the choice of planting plan. In the process of crop planting, whether farmers can comprehensively consider the impact of market price fluctuations, climate change and related commodities (substitutes and complementary products) on the sales unit price, and then make reasonable prediction and estimation of sales volume and output of agricultural products, which has far-reaching significance for the correct choice of planting plan. At the same time on the basis of fully considering the unique properties of different terrain, need to study the diversity of crop species and the adaptation of environment, clever use of refinement means such as rotation and terrain partition, constantly optimize planting layout strategy, and implement dynamic adjustment mechanism, to ensure that planting scheme can follow the environmental change, accurately realize the maximum maximization under the established conditions. In order to meet the farmers' yearning for a better life, this paper reasonably arranges the replacement planting of the optimal crops on various types of land in different seasons, which can effectively balance the unsalable sales and reduced sales caused by the large gap between the expected sales volume and the actual production volume, so as to maximize the annual net income. In view of the uncertainty of crop market and yield, especially the dynamic balance between per-mu yield and expected sales volume, this paper proposes targeted planting adjustment strategies to ensure the effectiveness of planting scheme and the stability of income.
Keywords: Optimization model; Crop planting; Sustainable development; Regression model

1 INTRODUCTION

In the research field of crop planting models, numerous previous studies have primarily focused on certain key factors, such as soil fertility and basic market demands [1,2]. These works have laid a foundation for agricultural planting planning. However, with the increasing complexity of the agricultural environment [3], their limitations have become more prominent. They often fail to comprehensively consider market price fluctuations, climate change, and the intricate relationships among crops, including substitution and complementarity. As a result, the planting recommendations provided lack the necessary specificity and adaptability to meet the diverse needs of farmers in different planting scenarios.

This paper aims to address these limitations and optimize crop planting strategies. By integrating agricultural knowledge with mathematical modeling and data - driven methods, a comprehensive analysis of multiple factors is conducted. The research focuses on the period from 2024 - 2030, aiming to optimize crop planting schemes while considering the dynamic balance between per - mu yield and expected sales volume.The growth rate or decline rate involved in the existing literature is given in the form of interval, and the exact value is not found for accurate calculation and approximation error in analysis, and key details such as the specific value of the planting area and the degree of spatial dispersion are not fully considered.To further verify the superiority and applicability of the established model, this paper compares it with the traditional optimization model of crop planting scheme. Traditional models often consider only a single factor or a few factors, while the model established in this paper considers many factors, including market price fluctuations, climate change, substitution and complementarity among crops. Through comparison, the model established in this paper in the optimization of planting scheme, improve economic benefit has obvious advantages, specifically, the traditional model often can only give relatively general planting advice, and the model established in this paper can according to the specific situation of different plots, different crops, give more detailed and specific planting scheme, so as to better meet the actual needs of farmers.

This paper defines key assessment dimensions considering different land types, using an identification system from A to F, and takes farmers' actual interests into account. A model is established to calculate the annual profit of crop sales, considering variables like annual crop sales volume, per mu yield, and planting costs. Different situations based on the relationship between per - mu yield and expected sales volume are analyzed, with risk coefficients introduced to account for uncertainties. The influence of commodity correlations on the planting scheme is explored through a linear programming model, considering substitution and complementarity coefficients. Through these efforts, this paper aims to help farmers make more scientific planting decisions, maximize their annual net income, and contribute to the sustainable development of agriculture [4]. On the basis of the basic planning scheme, this paper further considers and improves the fluctuation of the risk coefficient, enhances the application of the scheme, and objectively considers the impact of the relationship between the per-mu yield and the expected sales volume on the profit amount, which is in line with the actual situation. The model is based on data operation, with concise design and strong practicability.

2 THE OPTIMIZATION OF 2024 ~ 2030 CROP PLANTING SCHEME

2.1 Variable Declaration

Integrating agricultural knowledge, in this paper, exploring the optimal path to optimize planting strategy, it is supposed to comprehensively balance the constraints of cultivated land area with the specific environmental requirements of crop growth [5,6]. Based on these considerations, this paper initially defines the following key assessment dimensions. For land type factors, the identification system from A to F can be adopted to correspond to the plots in dry land, terraces, hillsides, irrigated land, ordinary greenhouses, and smart greenhouses,deeply concerned about the actual interests and expectations of farmers. In this paper, the annual profit Sm from 2024 to 2030 is set as the core standard to measure the success of the planting scheme. In order to accurately grasp the multiple factors affecting the annual profit S_m, this paper further analyzes the key variables such as annual crop sales volume, q_j, F_j, per mu yield, Q_m, annual total planting cost C_m, crop unit planting cost C_j, planting area α_j and crop unit selling price y_j.

2.2 Optimization Of The Planting Scheme

2.2.1 Model establishment

After considering multiple influencing factors [7] ,The formula for calculating the profit of crop sales can be derived. The core of this formula is the difference between profit and cost. Further establish the following formula:

$$\begin{cases} \sum_{i=1}^{n} S_m = \sum_{i=1}^{n} Q_m - \sum_{i=1}^{n} C_m \\ Q_m = q_j \times F_j , C_m = C_j \times \alpha_j \end{cases} \tag{1}$$

Similarly, when the excess portion is sold at 50% of the 2023 sales price, the formula is as follows:

$$\sum_{i=1}^{n} S_m = \sum_{i=1}^{n} 0.5 q_j \left(F_j + y_j \right) \tag{2}$$

2.2.2 Solutions

In order to prevent production reduction, each crop cannot be continuously repeated on the same plot, and to ensure soil conditions, all types of plots must be grown every three years. According to the above formula, the following conclusions are drawn as shown in Table 1:

Table 1 Six Optimal Crops of Ground Types(1)

Place	Season 1 Optimal Crop	Season 2 Optimal Crop	Optimal Bean Crop
Flat Dry Land Bench Terrace Shoulder	No.1 Sweet Potato No.2 Buckwheat		Black Soya Bean
Irrigable Land	Cucumber	Cabbage	Cowpea
Ordinary Greenhouses	Cucumber	Mushroom	
Smart Greenhouse	No.1 Cucumber No.2 Water Cabbage		

In dry lands, terraces and mountain slopes, sweet potatoes are the most profitable non-legume crop, while black beans have the greatest potential among legumes. Chinese cucumber had the best yield in the second quarter; cowpeas had the best yield in the bean crop. In greenhouse planting, cowpea always leads the lead in bean crops, not affected by season and greenhouse type. The first season of the cucumber, and the second quarter of the mushroom is the best income; in the wisdom greenhouse, the best economic benefits.Similarly, the conclusion of the optimal planting scheme for bean crops is shown in Table 2:

Table 2 Six Optimal Crops of Ground Types(2)

Place	Season 1 Optimal Crop	Season 2 Optimal Crop	Optimal Bean Crop
Flat Dry Land	No.1 Buckwheat		Black Soya Bean

Terrace Shoulder	No.2 Sweet Potato		
Irrigable Land	Cabbage	Eggplant	
Ordinary Greenhouses	Oil Barley	Mushroom	Cowpea
Smart Greenhouse	No.1 Elm Yellow Mushroom No.2 Yellow Heart Dish		

By comparison, the annual net income of the highest legume income is less than the top two non-legume crops. But to cultivate soil nutrition, legume crops will be grown at least once every three years from 2023. Therefore, minimizing bean planting in 2024-2030 is a necessary decision to improve the benefits, and this classification hypothesis is analyzed in this paper. The umes planted in 2023 should be replanted in 2026 and 2029; those not planted in 2023 should be planted in 2025 and 2028.Combining the above, the optimal planting scheme from 2024 to 2030 is finally obtained, as shown in Table 3:

Table 3 Optimal Planting Scheme from 2024 to 2030

2023	2024	2025	2026	2027	2028	2029	2030
√	No.1	No.2	√	No.1	No.2	√	No.1
-	No.1	√	No.1	No.2	√	No.1	No.2

Note: √ Indicates the year when the bean crop was grown

3 OPTIMIZATION OF PLANTING PLANS BASED ON DYNAMIC BALANCE BETWEEN YIELD PER MU AND EXPECTED SALES

When analyzing the crop planting scheme, the dynamic balance between the per-mu yield and the expected sales volume should be accurately considered, based on the calculation of the smaller values [8]. If the yield per mu volume is lower than the expected sales volume, the actual available volume is limited by the yield per mu, and the inventory cannot meet the expectation; otherwise, the part exceeding the expected sales volume will be unsalable. This paper adopts the conditional classification discussion strategy, and deduce the annual profit calculation model when the yield per mu yield is greater than or less than the expected sales volume, so as to determine and optimize the planting strategy and maximize the revenue [9].

3.1 The Per-Mu Yield Hxj < The Expected Sales Volume Qxj

3.1.1 Model establishment

The profit S_{xj} is calculated as follows, in which the annual sales Q_{xj} is calculated from the per-mu yield H_{xj}.

$$\begin{cases} S_{xj} = \sum_{i=1}^{n} Q_{xj} - C_x, \\ C_x = \alpha_{\mathrm{j}} \times \sum_{i=1}^{n} C_{xj}, \\ Q_{xj} = P_{xj} \times H_{xj} \times \alpha_{\mathrm{j}} \end{cases} \tag{3}$$

3.1.2 Risk adjustment of mu yield

Considering the fluctuation of per-mu yield within the range of ± 10% and its uncertainty, under the premise of per-mu yield as the key indicator affecting the annual sales,Introduce risk coefficientθ, Reexpressed the possibility of a surge or drop in the yield of a certain crop due to climate change, insect disasters and other factors. List the adjusted formula:

$$Q_{xj} = P_{xj} \times H_{xj} \times \alpha_j \times \theta \tag{4}$$

3.1.3 Fluctuation of grain crop sales price

For food crops, the annual sale price P_{xj} basically stable, so there's no need to do too much calculation.

3.1.4 Fluctuation of sales prices of vegetable crops

$$P_{xv} = P_{2023v}(1+5\%)^{x-2023} \tag{5}$$

3.1.5 The fluctuation of the sales price of edible fungus crops

Among all measurable fungus crops, the selling price of morels showed a significant decline of 5% per year, which led the fluctuation of 1% to 5% in fungus crops. Based on careful consideration of economic interests, this paper decided not to include the cultivation plan in the planning period from 2024 to 2030. Therefore, in this round of analysis, this paper will focus on evaluating and calculating the price fluctuations of other bacterial crops besides mochella, to ensure the optimization of planting strategies and maximize profits.To this regard, the fluctuation coefficient is introduced λ , represents the extent of the price change of edible fungi.

$$P_{xm} = P_{2023m}(1-\lambda)^{x-2023}, (0.01<\lambda<0.05) \tag{6}$$

3.1.6 Objective function after synthesis

$$\begin{aligned} S_{xj} = \sum_{i=1}^{n} \theta[P_{xc} \times H_{xc} \times \alpha_c + P_{2023v}(1+5\%)^{x-2023} \times H_{xv} \times \alpha_{xv} \\ + P_{2023m}(1-\lambda)^{x-2023} \times H_{xm} \times \alpha_m] - \sum_{i=1}^{n} \alpha_j \times C_{xj} \end{aligned} \tag{7}$$

3.2 The Per-Mu Yield Hxj > The Expected Sales Volume Qxj

$$\begin{cases} S_{xj} = \sum_{i=1}^{n} Q_{xj} - C_x , \\ C_x = \alpha_j \times \sum_{i=1}^{n} C_{xj} , \\ Q_{xj} = P_{xj} \times q_{xj} \times \alpha_j \times \theta \end{cases} \tag{8}$$

Use the expected sales q_{xj} to calculate sales Q_{xj}. At this time, the risk factors of per-mu yield and the sales price of each crop are the same as 3.1.

3.2.1 Expected sales of wheat and corn fluctuate

$$q_{xc'} = q_{2023} \times (1 \pm \mu)^{1-2023}, (0.05<\mu<0.1) \tag{9}$$

3.2.2 Volatility in the expected sales volume of other crops

$$q_{xo} = q_{2023} \times (1 \pm 5\%)^{1-2023} \tag{10}$$

3.2.3 Objective function after synthesis

$$\begin{aligned} S_{xj} = \sum_{i=1}^{n} \theta \ \{P_{xc'} \times \alpha_{c'} \times [q_{2023} \times (1 \pm \mu)^{1-2023} + q_{oc}] \\ + P_{2023v'}(1+5\%)^{x-2023} \times q_{xv'} \times \alpha_{v'} \\ + P_{2023m'}(1-\lambda)^{x-2023} \times q_{xm'} \times \alpha_{m'}\} - \sum_{i=1}^{n} \alpha_j \times C_{xj} \\ (0.01 < \lambda < 0.05, 0.05 < \mu < 0.1) \end{aligned} \tag{11}$$

3.3 The Optimized Result

By substituting actual data into the model for solving, the optimal planting plan from 2024 - 2030 is obtained. Among grain crops, buckwheat and sweet potato each account for 30% of the planting proportion, and the remaining grain crops together account for 40%. For legume crops, only black soybeans or cowpeas are selected. Among vegetable crops, eggplant accounts for 36% and cabbage accounts for 26%, and the remaining vegetables together account for 48%. Compared with the previous plan, the planting areas of buckwheat and sweet potato increase by 52 mu and 46 mu respectively, with an increase - decrease relationship among other grain crops. The planting areas of kidney beans and cowpeas decrease by 49 mu and 26 mu respectively, while those of potatoes and cucumbers increase by 27 mu and 46 mu respectively, and the areas of other vegetables decrease slightly.

4 THE OPTIMAL PLANTING SCHEME RELATED TO COMMODITY CORRELATION

4.1 Establishment Of The Linear Programming Model

$$\sum_{i=1}^{n} S_m = \sum_{i=1}^{n} Q_m - \sum_{i=1}^{n} C_m \tag{12}$$

4.2 Mechanism of the Influence of the Correlation

4.2.1 Alternative influence mechanism

To measure the degree of substitution between goods, the substitution coefficient is introduced $k_{y_1y_2}$ $k_{y_1y_2}$, The larger they are, the stronger the substitution. With $y_{2,x}$ represents the expected sales volume at this time,using $y_{2,x'}$ Indicates the original expected sales volume, $\alpha_{i,a,x}$ indicates the crop area planted on block I in year x a:

$$y_{2,x} = y_{2,x'} - k_{y_1y_2} \times \alpha_{i,a,x} \tag{13}$$

4.2.2 Complementary sex influence mechanism

Introducing the complementarity coefficient $\varphi_{y_1y_2}$ to measure the complementarity of agricultural products, $\varphi_{y_1y_2}$. The greater the complementarity, the stronger the vice versa。 At this time with $Q_{2,x}$ represents the expected sales volume at this time,using $Q_{2,x'}$ indicates the original expected sales volume:

$$Q_{2,x} = Q_{2,x'} + \varphi_{y_1y_2} \times \alpha_{i,a,x} \tag{14}$$

4.2.3 Correlation between sales volume and price

The increase of demand is positively correlated with the increase of price and demand, which leads a positive correlation coefficient $\omega_{P,Q}$.

$$Q_{y,x} = Q_{y,x'} + \omega_{y_1y_2}\left(y_{2,x} + \overline{y_{2,x}}\right) \tag{15}$$

4.2.4 Correlation between planting cost and price

The correlation coefficient is introduced $\upsilon_{c,p}$,Planting costs increase, and market prices rise. $C_{2,x}$ means the cost of planting, $\overline{C_{2,x}}$ represents the average planting cost.

$$Q_{y,x} = Q_{y,x'} + \upsilon_{y_1y_2}\left(C_{2,x} + \overline{C_{2,x}}\right) \tag{16}$$

4.3 The Result of The Correlation Coefficient

After data simulation, the solved correlation coefficient value is shown in the following:

$k_{y_1y_2}$=0. 25, $\varphi_{y_1y_2}$=0. 3, $\omega_{P,Q}$=0. 15, $\upsilon_{c,p}$=0. 2

After considering the substitutability and complementarity of various crops and the correlation between expected sales volume, sales price and the cost of planting, the optimal planting strategy from 2024 to 2030 was: buckwheat and sweet potato accounted for 30% for food crops and 40%; bean crops selected black beans or cowpea; among vegetable crops, eggplant accounted for 36 plants, and other vegetables accounted for 48%.

5 CONCLUSION

This paper considers many factors such as market price fluctuation, climate change, substitution and complementarity among crops, and studies crop cultivation deeply based on the optimization model. By constructing the specific yield calculation formula and combining the parameters of risk coefficient and fluctuation coefficient, the planting scheme of different plots and different crops is optimized. The results show that non-beans such as sweet potato and cucumbers should be planted in irrigated land, which can effectively improve economic benefits. This paper considering the dynamic balance between mu yield and expected sales, and introduce the risk coefficient to reflect the influence of climate change, diseases and insect pests and the correlation between commodities, further introduce the fluctuation coefficient, the planting scheme more detailed optimization, the results show that in food crops, buckwheat and sweet potato planting proportion appropriate increase, bean crops should choose black beans or cowpea to improve the efficiency. This paper innovatively considers many practical factors, and introduces the risk coefficient and fluctuation coefficient to enhance the practicability of the model, while taking into account the influence of the correlation between commodities on the planting scheme. The research results of this paper have important guiding significance for the future crop planting, and can help farmers to make planting plans more scientifically and improve the yield and quality of crops. It is of great significance to improve the economic benefits and realize the sustainable development of agriculture, and is expected to provide more comprehensive and precise support for the agricultural development in the future.Based on the research of this paper, the model parameters can be refined in the future to obtain more accurate planting schemes.

COMPETING INTERESTS

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

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