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Research on Crop Allocation and Revenue Analysis in Farmland Based on Linear Programming Models

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Abstract: *With the continuous growth of the global population and the increasing demand for agriculture, realizing the efficient and sustainable development of agricultural production under limited land resources has become one of the major challenges for modern agricultural management. In this context, the use of quantitative methods, such as linear programming, to optimize farmland crop allocation to enhance economic returns and resource utilization efficiency has become a key research direction for modern agricultural management. Specifically, based on the linear programming model, this paper investigates the optimization problem of crop planting strategies aiming to maximize returns. The optimal planting scheme from 2024 to 2030 was determined by the linear programming model, and the annual income is about 3 million yuan, which is more stable. The model results show that the optimized planting scheme can effectively maintain and improve the annual income level under different external conditions, which provides important theoretical support and practical guidance for modern agricultural management.*

Keywords: *Linear planning, Optimization, Economic Effects, Resource Utilization*

1. Introduction

Global climate change has led to frequent extreme weather events, threatening agricultural systems and destabilizing yields. tens of billions of dollars in crop losses are incurred annually due to extreme weather, according to FAO. In addition, pest and disease problems are severe, and chemical pesticides are less effective and also harmful to the environment [1]. With population growth and diminishing land resources, it has become urgent to improve crop yields and quality. Therefore, the application of on-farm crop allocation in agriculture is highly emphasized and offers the possibility of solving these problems [2]. In this study, farmland crop allocation and revenue analysis are conducted to maximize farmland resources and economic returns and to ensure sustainable agricultural development [3]. It reveals the mechanism of crop-economy interaction to provide support for maximizing the green economy and to enhance crop yield quality and economic effect [4]. The research results are expected to maximize the economic effect of allocation.

This study aims to optimize the crop planting strategy through mathematical modeling to determine the planting area based on the given data to maximize the revenue. The data were first preprocessed by replacing the crop name with the crop number, and for the convenience of the following arithmetic calculations, the average of the range was taken as the selling unit price. A linear programming model was then developed: setting the variables, listing the objective function, and analyzing the constraints. The enumeration method was then applied and iterations were performed to arrive at the final solution. Finally, the model was tested and evaluated, and suggestions for improvement were made to increase the depth of the study and utilize techniques such as big data. The whole research process includes data processing, model building, solution analysis, and result evaluation, which provides a scientific and reasonable planting strategy for the rural planting industry and maximizes the effect.

2. Linear Programming Model for Crop Planting

The data for this study was obtained from https://www.mcm.edu.cn/. According to the data found that the crop name as a Chinese character can not be processed, then the crop name was changed to the crop number. It was found that one of the data characteristics of the sales unit between floating within a certain range, to facilitate the following arithmetic calculations, take the average value of the range as the sales

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unit price. In the process of constructing a linear programming model, 0-1 planning is an auxiliary means [5]. Specifically, a 0-1 variable y was introduced, which was used to explicitly indicate whether the crop was to be planted on the plot or not, ensuring the model's accuracy and flexibility in the decision-making process.

First, set the variables. e t $s_{n,i,k}$ denotes the area (in acres) of plot i in the nth quarter in which k crop is planted. Immediately after that, let $y_{n,i,k}$ denotes whether k crop is planted or not in plot I in the nth quarter so that it is equal to 1 for planting and equal to 0 for not planting. Finally, let me denote the total annual income.

Then list the objective function Max I, according to the revenue situation, in two cases to refine the objective function: if the crop yield exceeds the expected sales: listed over the part of the total revenue objective function can not be sold, to facilitate the subsequent solution will be converted into a very small value problem objective function

$$\text{Min I} = -\sum_{n=1}\sum_{i=1}\sum_{k=1}(p_k * \min(s_{n,i,k} * q_k, c_k) - d_k * s_{n,i,k}) \tag{1}$$

If the portion of sales volume exceeds the expected 50% of the 2023 selling price, the total revenue objective function can be expressed as follows

$$\text{Min I} = -\sum_{n=1}\sum_{i=1}\sum_{k=1}(p_k * \min(s_{n,i,k} * q_k, c_k) + 0{,}5\text{Max}(s_{n,i,k} * q_k - c_k, 0) - d_k * s_{n,i,k}) \tag{2}$$

Finally, the constraints are analyzed:

Based on the requirement that crops grown on the same plot cannot be grown in heavy crops, the following constraints are obtained:

$$s_{n,i,k} * s_{n+1,i,k} = 0 \quad \forall n, i, k \tag{3}$$

Based on the requirement that each plot be planted with a legume crop at least once in three years, the following constraints are obtained: legume

Planting constraints.

$$\sum_{n}^{n+b} y_{n,i,k} \geq 1 \quad \forall n, i, k \tag{4}$$

Flat and dry land, terraced land, and hillside land are only suitable for growing food crops for one season per year. From the analysis of Appendix 1, it can be seen that crops No. 1~15 can only be planted on flat dry land, terraced land, and hillside land, and at the same time, only crops No. 1~15 can be planted on the above-mentioned cropland types. Accordingly, the following constraints are derived: land constraints for cultivation.

$$\sum_{i}\frac{y_{n,i,k} + y_{n+1,i,k}}{2} \leq 1 \quad k \in (1,15), i \in \{(A_1, A_6), (B_1, B_{14}), (C_1, C_6)\} \tag{5}$$

$$\sum_{k}\sum_{i}\sum_{n} s_{n,i,k} = 0 \quad k \in (16,41), i \in \{(A_1, A_6), (B_1, B_{14}), (C_1, C_6)\} \tag{6}$$

$$\sum_{k}\sum_{i}\sum_{n} y_{n,i,k} = 0 \quad k \in (1,15), i \in \{(D_1, D_8), (E_1, E_{16}), (F_1, F_4)\} \tag{7}$$

Consider that in reality, water-consumed land can be planted with a single season of rice or with two seasons of vegetables. If two seasons of vegetables are grown on irrigated land, the first season requires the cultivation of vegetable crops other than cabbage, white radish, and carrot, and the second season the cultivation of one of cabbage, white radish, and carrot. At the same time cabbage, white radish, and carrot can only be grown in the second season in the watered land. Based on the above requirements, the following constraints are derived: planting season constraints.

$$y_{16,i,t} + y_{k,i,t} = 1 \;\; k \in (17,34), i \in (D_1, D_8) \tag{8}$$

$$\sum_k s_{n,i,k} \le x_i \;\; k \in (38,34), i \in (D_1, D_8) \tag{9}$$

$$\sum_i \frac{(y_{n,i,k} + y_{n+1,i,k})}{2} \le 1 \;\; k = 16, i \in (D_1, D_8) \tag{10}$$

Ordinary greenhouses can grow two seasons of crops per year, with vegetables (cabbage, white radish, and carrot except) in the first season, and edible mushrooms in the second season.

$$y_{n,k,i} = 0 \;\; if \; n\%2 == 0 \;\; i \in (E_1, E_{16}), k \in (17,34) \tag{11}$$

$$y_{n,k,i} = 0 \;\; if \; n\%2 == 0 \;\; i \in (E_1, E_{16}), k \in (38,41) \tag{12}$$

$$\sum_i s_{n,k,i} \le x_i \;\; i \in (E_1, E_{16}) \tag{13}$$

According to the requirements, the smart greenhouses can grow two seasons of vegetables per year (cabbage, white radish, and red radish) except that they can get the following constraints: smart greenhouse constraints.

$$\sum_i s_{n,k,i} \le 2x_i \;\; i \in (F_1, F_{16}), k \in (17,34) \tag{14}$$

The area of each crop in a single plot should not be too small, let crop k occupy the minimum ratio of a in i plots, and the maximum number of crops grown in the same plot is n, where a is the threshold value of the proportion of crop occupancy, the following constraints can be obtained: minimum land area constraints.

$$y_{n,k,i} = 0 \;\; if \; n\%2 == 0 \;\; i \in (E_1, E_{16}), k \in (17,34) \tag{15}$$

$$y_{n,k,i} = 0 \;\; if \; n\%2 == 0 \;\; i \in (E_1, E_{16}), k \in (38,41) \tag{16}$$

The planting plots for each crop per season should not be too dispersed and the maximum planting area for each crop should not be larger than the planting area of the plot, so the following constraint is derived: the dispersion constraint.

$$s_{n,k,i} \ge a x_i \;\; if \;\; y_{n,k,i} = 1 \tag{17}$$

By setting decision variables to describe the relationship between the area planted and whether or not k crops are planted on plot i in the nth season, the objective function is listed according to the two cases respectively, and finally, the constraints are analyzed.

3. Model Solution and Result Analysis

The above-constructed model is solved by linear programming. Assuming a value for the above parameters n and k, using the enumeration method, different crops are allocated to the corresponding plots, listing all the allocation schemes that satisfy the constraints, and comparing the final yield values of the different schemes through more than a thousand iterations, eliminating the schemes with lower yields, retaining those with higher yields, and finally retaining the scheme that has not been eliminated as the final scheme. Change the values of n and k. Repeat the above process, change n and k several times to analyze the final plan, and then get the optimal values of n and k by combining the actual needs of field management.

The above model was solved using Matlab and Jupiter Notebook and the results obtained for the year 2026 are shown in Table 1 below, which selects a portion of the plots of different species to show those crops that were grown in the plot in the first and second seasons respectively as well as to show the acreage planted to those crops, where n and k are taken to be 5 and 20%, respectively.

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Table 1 Partial information on plot planting in 2026

Planting plot	Crop number	Crop Name	Crop type	Planting area/mu	Planting season
A1	11	Buckwheat	food	26	Single season
A1	13	Sweet potato	food	54	Single season
B1	15	Barley	grain	13	Single season

In this year's planting program, for example, only 10 plots, or 12.1% of all plots, were not selected for mixed cropping.

Therefore, when planning the planting program for each plot, the proportion of land occupied by mixed cropping plots should be increased to reduce the output of crops that exceed the expected sales. From the analysis of the results given in the optimal plan, most of the plots in the optimal plan were planted with mixed planting

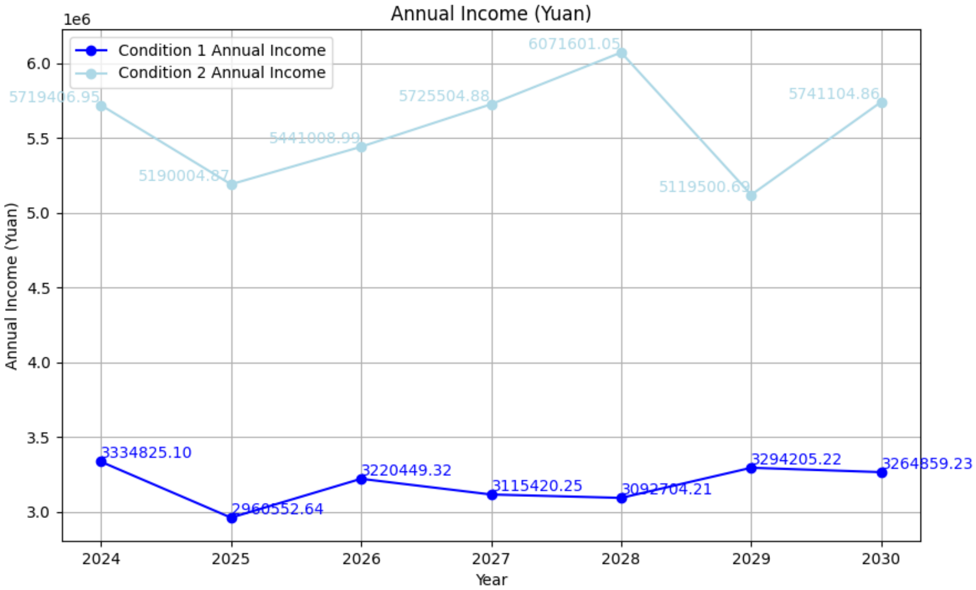

Figure 1 Comparison of the results of the line of annual gross income over time for the years of the two-conditional interval

Based on the planning scenarios from 2024 to 2030, the planting arrangement information of the planned crops is substituted into the objective function to calculate the total annual income for each year, figure 1 show the change in the total annual income of each year under the planning scenarios over time, and the income is mostly maintained at about 3 million dollars and is relatively stable.

Comparing the two crop treatment options that exceeded the expected sales volume, it can be seen that the option that reduced the price of the slow-moving portion of the crop resulted in higher annual revenues.

As shown in Fig. 2, it is observed that as the value decreases gradually, the returns tend to increase and then decrease. As a value of a decreases from 20% to 15%, there is a significant increase in the return and as a value of a further decreases to 10%, the return decreases as compared to 15%. This phenomenon suggests that at a particular value of a, the return is maximized. Further analysis of the multiple values of a reveals that at 13% a, the gain is maximized compared to the other values. Therefore, the final result is set at 13%.

In terms of plot demarcation, firstly, the numerical demarcation criterion of a*Xi was used in this study to divide the plots into n-1 plots, with the area of each plot being a*Xi. After the n-1 plots were divided according to this criterion, the remaining area of the plot was regarded as the nth plot. Each plot is planted with different crops, totaling n species. This strategy shows that as the value decreases, the plots become finer and less wasteful. However, when the value of a is too small, the value of n will also be small, and the area of the nth plot will be relatively large, which may lead to the waste of crops in that plot. Therefore, the value of a needs to be balanced so that it is neither too large nor too small to avoid

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both of these extremes. In addition, when determining the value of a, we must ensure that the minimum size of the plots is within an acceptable range to ensure that the division is reasonable and practical.

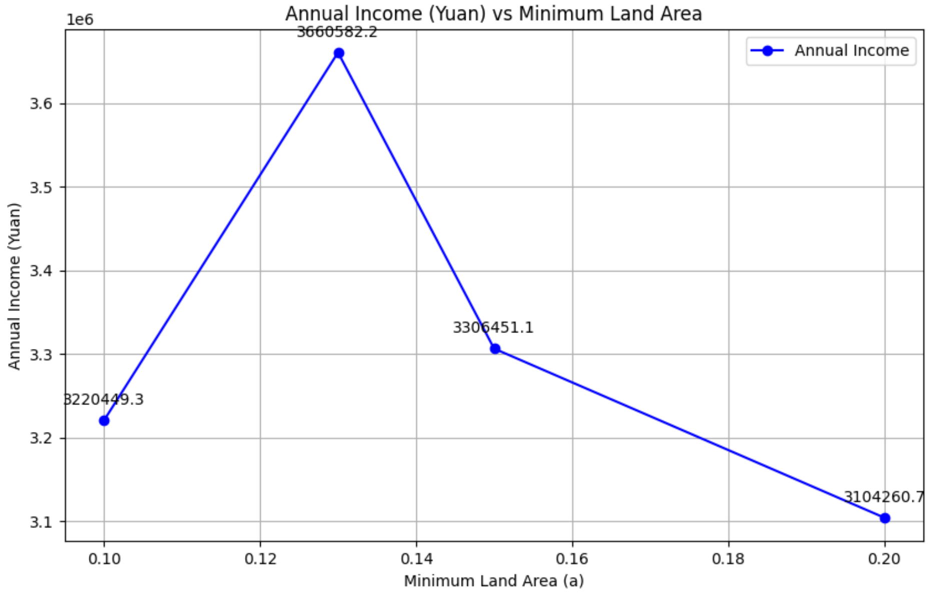

Figure 2 The minimum size of the plots

Analysis of n impact results: Based on the data presented in the data results as represented in Figure 3, it is observed that as the value of n increases gradually, there is a gradual increase in the returns. When the value of n is increased from 1 to 5, there is a significant increase in the revenue. This phenomenon indicates that the plot parameter n reaches its maximum value compared to other values. Therefore, the final result is set to 5.

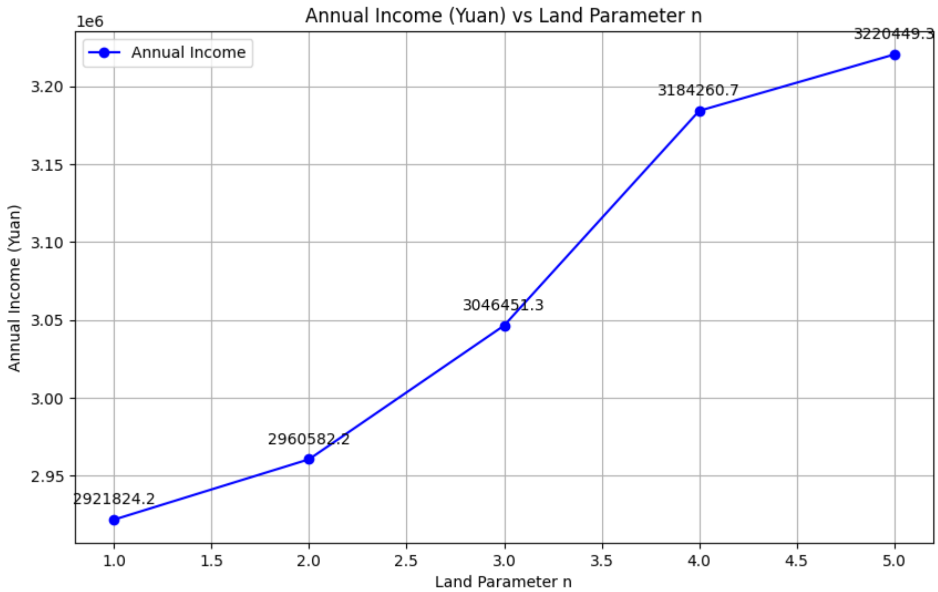

Figure 3 Impact of results of the number of parcels

As shown in Figure 3, an increase in the number n of crop types grown within a plot is often accompanied by a significant increase in final returns. This is because as n increases, the plot is more carefully divided into zones, realizing a higher mixing ratio, which positively affects returns. Specifically, an increase in the proportion of mixed plantings helps to better control the yield of each crop and prevent it from selling too much beyond expectations. When the planted area of a certain crop exceeds

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expectations, other crops can be flexibly planted on the remaining land to ensure that the yield of each crop can be fully utilized, ultimately maximizing returns.

However, when setting the value of n, the value of a must be considered carefully. When the product of a and n is greater than 1, the plot area may not be large enough to be divided into n parts, which will make the problem unsolvable.

In addition, it is worth noting that this model mainly focuses on analyzing the trends of the parameters n and a, and does not fully consider the field management problems that may be encountered in the actual planting process. Therefore, when applying this model to actual planting, it is necessary to fully integrate the actual situation and comprehensively consider various factors to ensure the smooth progress of planting activities and maximize the benefits.

4. Conclusions

Firstly, the optimization objective is determined as the maximum return from planting the crop. Crop yield per acre, sales price, expected sales volume, and planting cost per acre in this question to take the value of 2023, according to the conditions, these values for the determination of the value, then the decision variable to determine the return on crop cultivation is the area of the crop planted. From the above analysis, the objective functions under the two requirements are listed according to the different ways of handling the crop exceeding the expected sales volume. Based on the objective requirements, the following constraints are obtained: no re-cropping constraint, legume planting constraint, crop quarter constraint, crop cultivation constraint, minimum area constraint, and maximum number of crop mixes constraint. The objective function is solved by the enumeration method, which enumerates each cropping method of the crop and selects the cropping scheme with the highest yield, provided that the constraints are met. The text has some shortcomings due to the insufficiency of data. In the future, using big data modeling will be applied to planting strategies in many different situations.

This paper provides a research idea and framework applied to the field related to agricultural economic optimization and establishes a linear programming model to achieve the maximization of the economic effect of farmland crop allocation. The feasibility of the method is demonstrated by the relevant parameters.

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