

Study on Crop Cultivation Optimization Scheme Based on Linear Programming

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Abstract. Against the backdrop of the rural revitalization strategy, linear programming can optimize China's agricultural production by addressing resource scarcity and low efficiency issues through scientific decision-making. This study conducts statistical analysis of cultivation data, examining indicators such as land type proportions and crop yields, to assess cultivation efficiency. Based on these analyses, a linear programming model is constructed with multiple constraints including land suitability, cultivation cycles, and legume rotation requirements, while assuming stable variables such as sales volume, costs, and prices. Through calculations, the study reveals that wheat and corn are primary crops on plains and terraces (20-80 acres), while crops like millet and sorghum occupy smaller areas of 20-50 acres. Legume crops are rotated across different lands to maintain soil fertility. The research aims to provide farmers with scientific cultivation plans that maximize agricultural profits, thereby promoting sustainable agricultural development.

Keywords: Crop Cultivation Optimization, Linear Programming Model, Rural Revitalization, Sustainable Development.

1. Introduction

Against the backdrop of current agricultural development, our country is facing challenges such as tight arable land resources and low agricultural production efficiency. Especially during the key implementation phase of the rural revitalization strategy [1], how to achieve the scientification, scale-up, and maximization of benefits in agricultural production has become an important issue that urgently needs to be addressed. The optimization of crop cultivation is a key link in improving agricultural production efficiency. Traditional planting methods largely rely on experiential decision-making and cannot meet the needs of modern agricultural development. Linear programming, as an important technique in operations research, can provide an optimal allocation plan for crop cultivation by considering various constraints (such as land resources, seasonal changes, market demand, etc.). With the reform and development of the national economic structure, the development of the rural economy has become increasingly important. Under the existing economic system [2], the core of the rural economy lies in whether the production methods and scale of agricultural products match the societal demand. With the continuous advancement of technology [3], the rational use of digital technology [4] to efficiently predict the optimal planting plans for crops can significantly improve agricultural production efficiency and quality, reduce production costs, and create greater profit margins for farmers.

This paper proposes a scheme to optimize agricultural production through the application of linear programming, addressing the issues of scarce resources and low production efficiency in current agricultural development. Against the backdrop of the rural revitalization strategy, this has significant practical implications. Through statistical analysis of planting data, the planting efficiency of different plots and crops was assessed, providing foundational data support for constructing a linear programming model. This study constructed a linear programming model that includes various constraints, such as land suitability, planting cycles, and legume crop rotation requirements, and assumes that variables such as sales volume, costs, and prices remain stable. Model calculations revealed the planting areas and distribution of different crops on various plots. The research proposed a set of scientific planting plans aimed at maximizing agricultural profits and promoting sustainable

agricultural development, providing farmers with scientific planting guidance, and helping to increase agricultural output and farmers' income. This paper not only provides the construction and application of the current model but also proposes directions for model improvement, such as considering big data simulation and predictive conditions under extreme scenarios, to better plan farmers' crop planting schemes, ensuring farmers' interests while promoting the sustainable development of the national agricultural economy.

2. Visual Statistical Analysis of Crop Planting Data

This study's data comes from www.cnki.net. To analyze the data more intuitively, this research has performed data pivoting on the data provided by the official website. First, this paper has summarized the area proportions of different land types. As shown in Figure 1 and Figure 2, it can be observed that the area of terraced fields accounts for more than half of the total area of all land types, with the largest proportion, followed by the area of dry flatlands, while the area of smart greenhouses is the smallest. This lays the foundational conditions for model analysis.

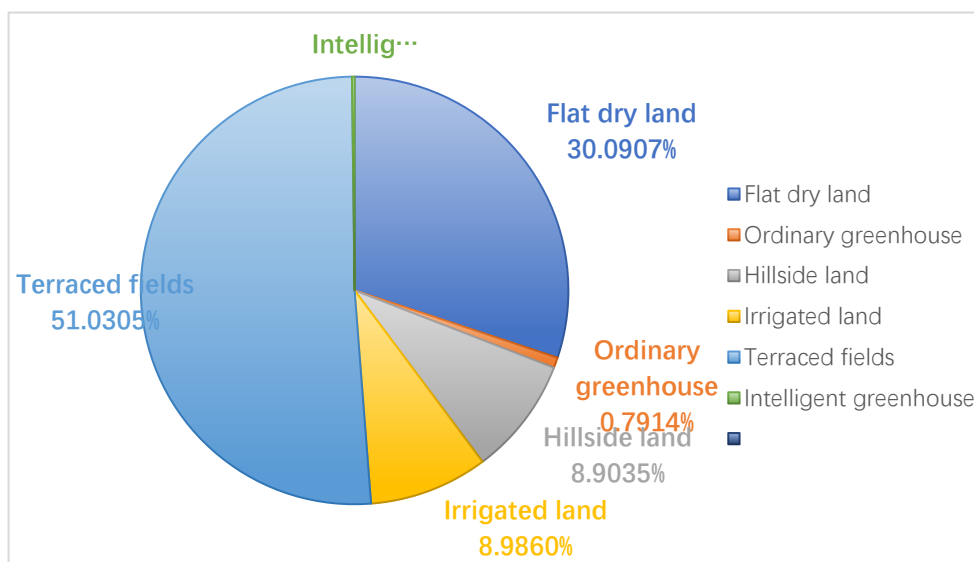


Figure 1. Area Proportion Chart of Different Plots

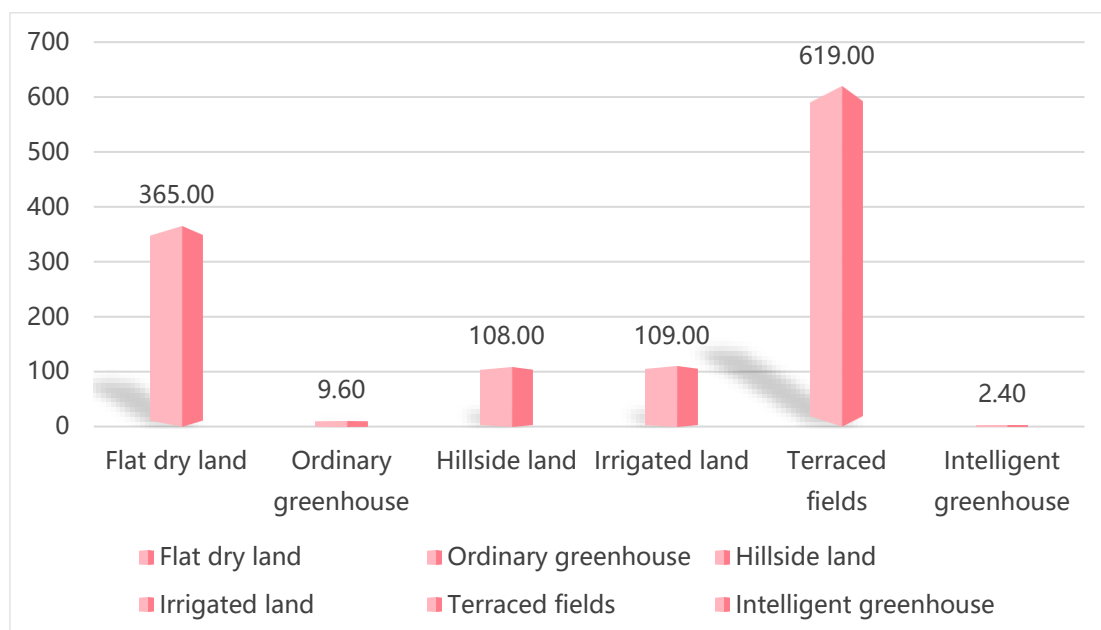


Figure 2. Total Area of Different Plots Chart

At the same time, in order to observe the crop yields of different plots more intuitively, this article aggregates relevant data and processes it for data pivoting. According to Figure 3, it can be observed that the total yield of the flat dry land is the highest. However, according to Figures 1 and 2, the area of the flat dry land is much smaller than that of the terraced fields. Therefore, it can be concluded that the planting efficiency of the flat dry land is higher than that of the terraced fields, meaning the yield per unit area of the flat dry land is higher. Based on this study, the planting plan for the flat dry land can be focused on to maximize profits.

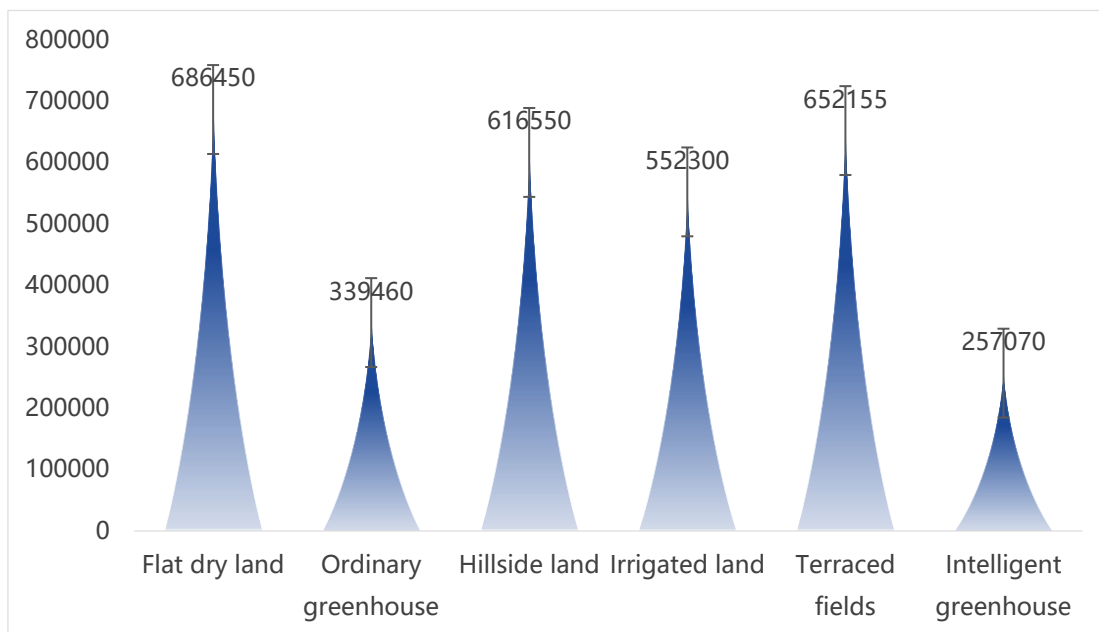


Figure 3. Total Crop Yield by Different Land Plots

Based on the above content, this study also conducted data pivoting processing on various types of crop data, as shown in Figures 4 and 5. It can be observed that the total production and planting area of grain crops, which are the foundation of people's livelihood, are relatively high, while the planting area and yield of vegetable crops are relatively small. In particular, the planting area and yield of high-value edible fungi crops are especially scarce. Therefore, this article can make appropriate adjustments when constructing models in the future to seek the optimal planting scheme.

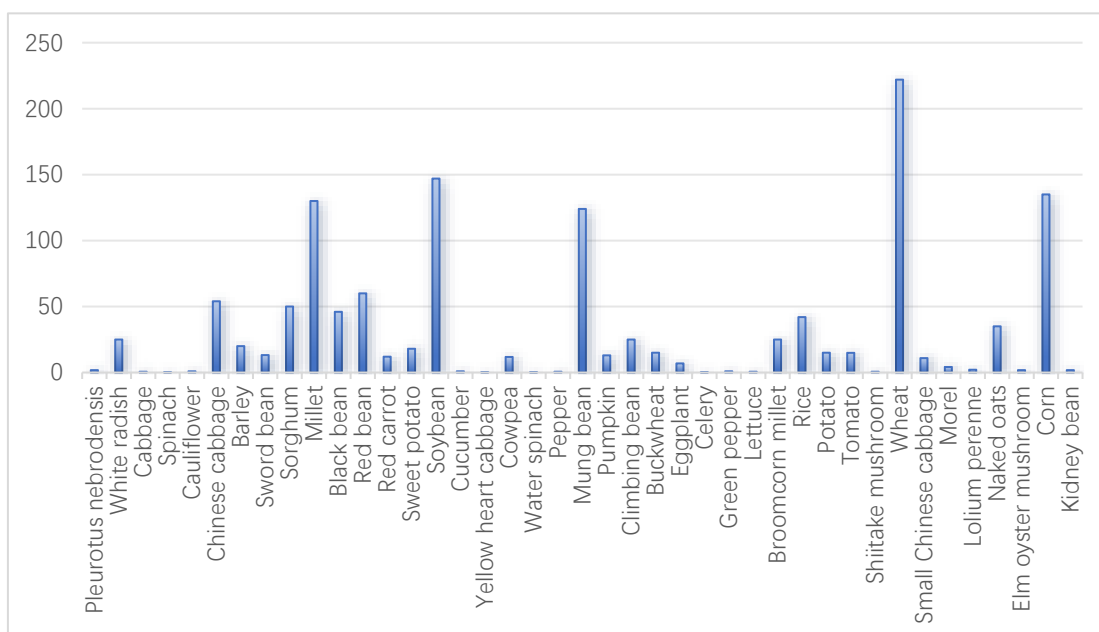


Figure 4. Total Area Planted for Different Crops

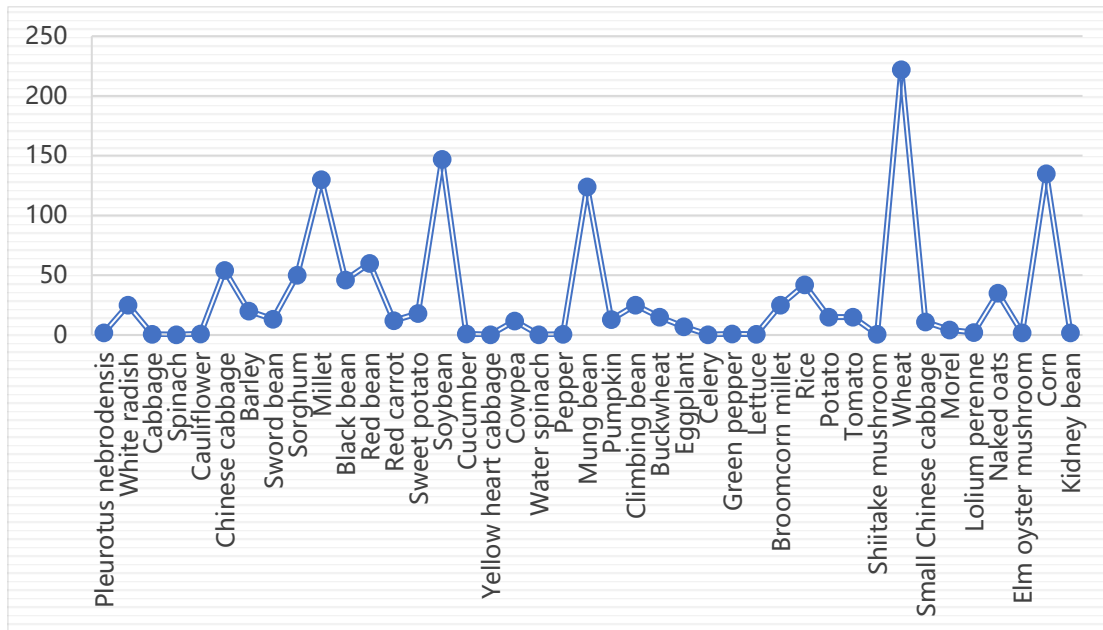


Figure 5. Total Yield Chart of Different Crops

For the optimal planting scheme, according to economic principles, the most important thing is still to obtain the greatest benefit with the smallest planting cost. Therefore, this study must analyze the planting costs and total sales revenue of different crops. As shown in Figure 6, this article compares the planting costs of different crops with their total sales revenue, and it can be observed that all crops are profitable, but their profit margins vary greatly. In particular, crops such as grains, beans, and edible fungi have relatively high profits. In the subsequent modeling analysis, these details will be given more attention, and the relevant data will be properly handled.

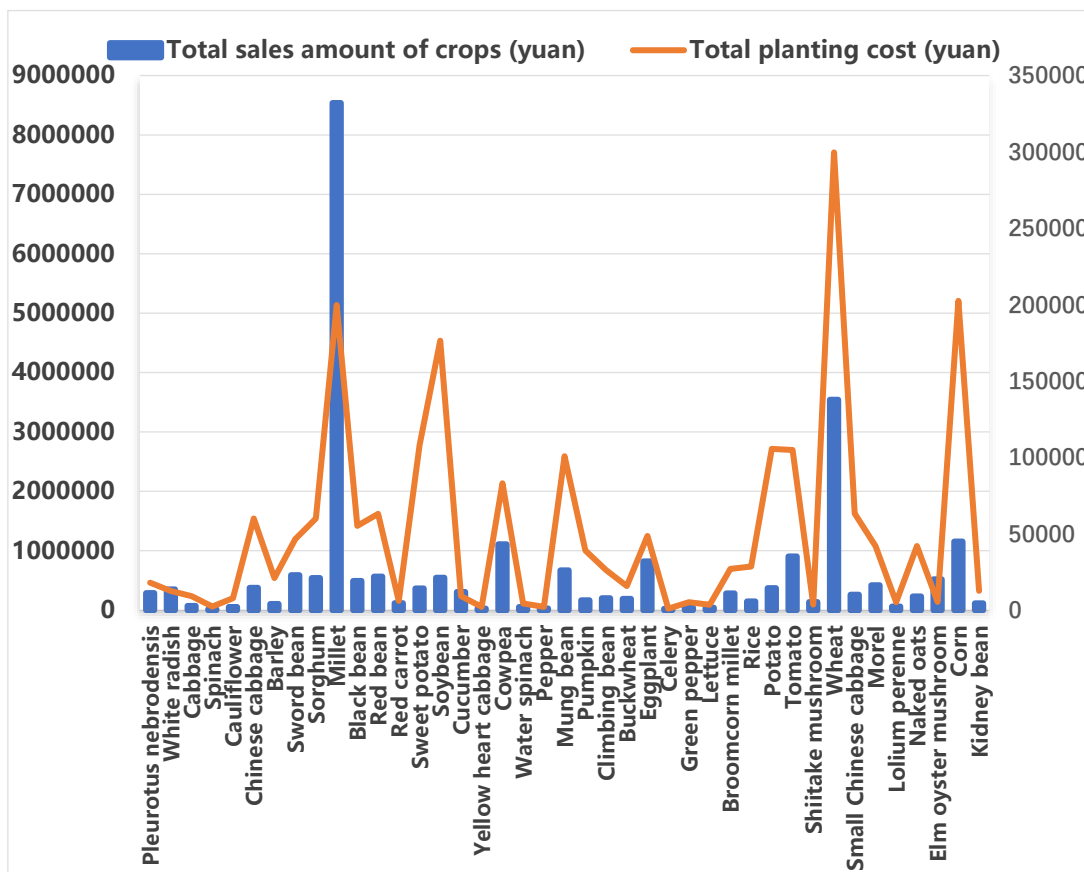


Figure 6. Sales Volume and Cultivation Cost Comparison Chart for Different Crops

3. Mathematical Model Design for Crop Planting Optimization

According to the research objectives of this article, it is necessary to propose the optimal planting plan for crops in this rural area from 2024 to 2030 under two different conditions. The planting of crops [5] is influenced by external factors such as seasons, soil conditions, market demand, etc., which requires the government [6] to continuously adjust the allocation of related resources in order to achieve the goals. After searching for relevant materials, many scholars [7, 8] believe that the linear programming model can flexibly adapt to different situations, helping agricultural producers adjust the allocation of resources according to actual needs, apply reasonable planting plans, and maximize agricultural output profits. Linear programming can not only allocate resources during the planting phase but also optimize resources throughout the entire agricultural supply chain. Considering that there is a relatively large amount of data and that it is necessary to derive the optimal planting plan for many years, the model construction is relatively complex. Therefore, this article chooses to build a linear programming model to simplify the planting conditions of crops to solve this problem.

For the optimal planting scheme discussed in this study, one of the criteria for evaluation is the maximization of crop profits. To accurately reflect the various factors affecting crop profits, this paper constructs the corresponding objective function to support the construction of a linear programming model [9].

3.1. Objective function of mathematical model

Objective function of a mathematical model:

(1) When the surplus beyond the expected yield is unsold, the profit for the crops is:

$$\max \text{Profit}_1 = \sum_i \sum_j \sum_t (P_i \cdot \min(X_{it}, Q_i) - C_i \cdot X_{it}) \quad (1)$$

(2) When the surplus production is sold at a discounted price, the profit for the crops is:

$$\max \text{Profit}_2 = \sum_i \sum_j \sum_t (P_i \cdot \min(X_{it}, Q_i) + \frac{P_i}{2} \cdot \max(X_{it} - Q_i, 0) - C_i \cdot X_{it}) \quad (2)$$

In the formula: X_{it} represents the total yield of crop type i in the t -th year (tons); Q_i is the expected sales volume of crop type i (tons); P_i is the unit price of crop type i (yuan/ton); C_i is the unit area cost of growing crop type i (yuan/mu); Y_i is the yield per mu of crop type i (tons/mu).

To make the model more realistic, this study has imposed certain constraints. The following will elaborate that the first constraint is to ensure that different plots can only grow crops that are suitable for that specific plot. This paper first restricts that plain dry land, terraced fields, and hillside land are suitable for single-season cultivation of grain crops (excluding rice):

$$\sum_{i \in Z^{1-15}} S_{ijt} \leq T_j, \forall j \in \{A^{1-6}, B^{1-14}, C^{1-6}\} \quad (3)$$

Secondly, irrigated land is planted with rice annually for a single season:

$$\sum_{i \in Z^{16}} S_{ijt} \leq T_j, \forall j \in \{D^{1-8}\} \quad (4)$$

Then, if the land is irrigated for two seasons of vegetable cultivation, the first season cannot plant cabbage, radish, or carrot, while the second season can only plant one of the three mentioned vegetables.

$$\sum_{i \in Z^{17-34}} S_{ijt} \leq T_j, \forall j \in \{D^{1-8}\} \quad (5)$$

$$\sum_{i \in Z^{35-37}} S_{ijt} \leq T_j, \forall j \in \{D^{1-8}\} \quad (6)$$

Again, irrigated land can be planted with single-crop rice or two crops of vegetables.

$$\sum_{i \in Z^{16}} R_{ijt} + \frac{\sum_{i \in Z^{17-34}} R_{ijt} + \sum_{i \in Z^{35-37}} R_{ijt}}{2} \leq 1, \forall j \in \{D^{1-8}\} \quad (7)$$

At the same time, ordinary greenhouses are used to grow two crops annually, with vegetables planted in the first season and edible fungi in the second.

$$\sum_{i \in Z^{17-34}} S_{ijt} \leq T_j, \forall j \in \{E^{1-16}\} \quad (8)$$

$$\sum_{i \in Z^{38-41}} S_{ijt} \leq T_j, \forall j \in \{E^{1-16}\} \quad (9)$$

Finally, the smart greenhouse cultivates two seasons of vegetables annually.

$$\sum_{i \in Z^{17-34}} S_{ijt} \leq 2T_j, \forall j \in \{F^{1-4}\} \quad (10)$$

In the formula: S_{ijt} represents the area (acre) of the i -th type of crop planted in the j -th plot in the t -th year, R_{ijt} represents the yield of the i -th type of crop planted in the j -th plot in the t -th year.

Secondly, each plot must be planted with leguminous crops at least once every three years.

$$\sum_t^{t+2} B_{ijt} \geq 1 \quad \forall_{j,t,i} \in \{\text{legumes}\} \quad (11)$$

In the formula: B_{ijt} represents the number of times legumes are grown in the j -th plot.

Third, the same crop cannot be continuously planted in the same plot.

$$R_{ijt} + R_{ijt+1} \leq 1 \quad \forall_{i,j,t} \quad (12)$$

In the formula: R_{ijt} represents the cultivation of crop type i in the j th plot in the year t .

Fourth, the planting area of each crop on each plot should not be too small (this study directly takes 50%).

$$S_{ijt} \geq aT_j \quad (13)$$

In the formula: T_j represents the area of the j th plot (acre).

Based on the above content, through relevant calculations [10], the following results can be obtained, and according to Figure 7, the conclusion of this article is:

Between 2024 and 2030, the open fields (including dry flatlands, terraced fields, hillside lands, and irrigated lands) and greenhouses (both conventional and smart greenhouses) were rationally planned according to the characteristics of different plots and the planting requirements of crops. Overall, grain crops are widely distributed for planting in dry land, terraced fields, and hillside areas to fully utilize these land resources for single-season cultivation; irrigated fields are mainly used for planting rice or vegetables, and vegetable cultivation is arranged for single or double seasons depending on the type of greenhouse; the cultivation pattern for regular greenhouses is one season of vegetables and one season of edible fungi, fully utilizing their production capabilities. Here is the specific planting situation of various crops in different years and fields:

For cereal crops, wheat is widely planted in flat dryland and terrace fields, such as plots A1, A2, A5, A6, which have seen wheat cultivation in the first season of multiple years, with planting areas fluctuating between 35-80 acres. In 2024, plot A1 had 80 acres of wheat planted in the first season, opting for a larger area of cultivation. Corn is also extensively grown in flat dryland and terrace fields, with plots like A3, A4 changing planting areas in the first season of different years. In 2024, plot A3 had 34 acres of corn planted in the first season. Millet, sorghum, broomcorn, oats, and barley are other cereal crops with relatively smaller planting areas compared to wheat and corn, and their distribution is more scattered. Plots B2, B3, B4 have seen millet, sorghum, and other crops planted in certain years, with areas ranging from about 20-50 acres.

For legume crops, including soybeans, black beans, red beans, mung beans, climbing beans, yardlong beans, sword beans, and kidney beans, among others, are cultivated in various plots to ensure that each plot is planted with at least one type of legume crop within a three-year period. For instance, Plot B1 was planted with 44.052632 acres of soybeans and 15.947368 acres of red beans in the first season of 2024. The cultivation took into account the expected sales volume and price of different legume crops in the market, ensuring that economic benefits are maximized while meeting the planting requirements.

For vegetable crops such as tomatoes, eggplants, spinach, bell peppers, cauliflower, cabbage, lettuce, pak choi, cucumbers, lettuce, chili peppers, water spinach, yellow heart vegetables, celery,

and Chinese cabbage, they are cultivated in irrigated fields and greenhouses. In some years, D1-D8 plots in the irrigated fields are used for vegetable cultivation during the first season, with the area varying depending on the size of the plot and the cultivation plan. In terms of greenhouse cultivation, the smart greenhouse has vegetable planting arrangements for the second quarter of every year from 2024 to 2030, while the regular greenhouse alternates between a season of vegetables and a season of edible fungi. Taking plots E1-E16 and F1-F4 as examples, there are variations in the area and types of vegetables planted in different years.

For mushroom crops such as shiitake, xianggu, bailingu, and morel, they are primarily cultivated in regular greenhouses, and the cultivation area is relatively smaller compared to vegetable crops. In greenhouse plots like B1-B14, the cultivation of mushrooms is arranged reasonably according to the planting plans for different years.

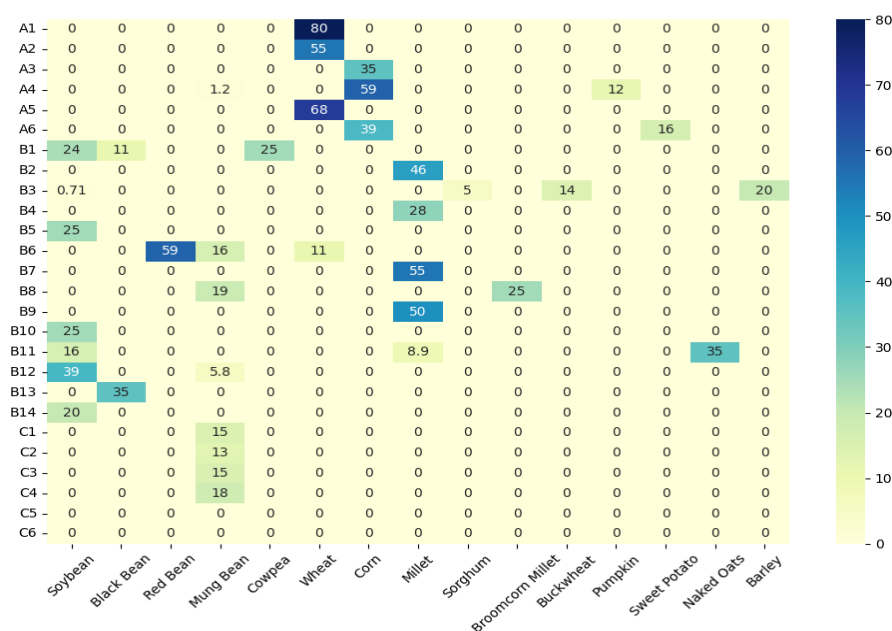


Figure 7. Study Results

4. Conclusion

This article constructs a linear programming model for crop profit and crop planting costs, considering the different types of crop planting plots and crop varieties. It first describes in detail how fixed factors affect crop profit and crop planting costs without the influence of variable factors. Then, it sets the constraints for the linear programming model. Using the data provided in the attachment as an example, the feasibility and effectiveness of the model are verified. When applying this model, conditions can be adjusted appropriately to solve practical problems. Additionally, the data involved in this article is relatively ideal, which reduces the universality and promotion ability of the model. For example, factors affecting crop yield and value are not entirely controllable in practice. Although China has a very "stringent" regulatory power over crop prices, it cannot completely prevent the occurrence of price fluctuations, no matter how small the probability. Whenever such events occur, farmers' income will suffer losses. However, China has long had solutions for such problems, namely relevant subsidy policies. If improvements are to be made to the model constructed in this article, the study suggests that further refinement can be achieved from the perspective of big data simulation. It is important to note that, based on the current model, additional predictive conditions for the cultivation of crops should be included, such as natural disasters, market fluctuations, and other extreme situations, as well as local customs and public aspirations. This can help our country better plan schemes for farmers to cultivate crops, ensuring the interests of farmers while promoting the sustainable development of the national agricultural economy.

This article provides a research approach and framework applied to the field of agricultural economic optimization. The conclusions above demonstrate the feasibility of the method. The models in this article can appropriately address issues in real life, such as farmers not being able to grasp the types and quantities of crops to plant, leading to overproduction or underproduction. This can cause significant fluctuations in crop prices and result in a situation where farmers' production costs exceed their income, known as the "agrarian distress" phenomenon. The models in this article can guide farmers in selectively arranging planting plans, adapting to local conditions, and achieving higher benefits.

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