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CROP PLANTING STRATEGIES BASED ON PARTICLE SWARM OPTIMIZATION ALGORITHM

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Abstract: In order to solve the problems of efficient utilization of limited cultivated land resources and sustainable agricultural development in the North China Plain, this study aims to maximize total profits from 2024-2030, and combines field inspection data to build a planting strategy optimization model. First, the 2023 crop yield per mu and planting area data are processed through the VLOOKUP function to determine the expected future sales volume; the lowest sales price is extracted and profits are calculated based on planting costs. After Python data cleaning and standardization, SPSSPRO is used to visually analyze the profit and income ratio of different plots (flat dry land, terraced fields, etc.) to screen high-quality crops. For the two scenarios of "total waste of excess sales" and "price reduction of excess sales", corresponding objective functions are constructed, constraints such as plot planting cycle, continuous cropping taboos, and bean crop rotation are introduced, and particle swarm optimization (PSO) is used to solve the optimal solution through Python. The results show that the model can effectively balance resource utilization, cost control and ecological constraints, and provide quantitative support for scientific planting decisions in the North China Plain.
Keywords: Particle swarm optimization; Crop planting strategy optimization; North China Plain; Objective function; Cultivated land resource utilization

1 INTRODUCTION

Agriculture is one of the most important industries in the world; it is my country's largest industry; and it is the foundation of national economic development [1]. Agriculture plays a vital role in food supply, economic growth and social stability. Since the 40 years of reform and opening up, the structural adjustment of planting and agricultural industries has made great contributions to ensuring my country's grain production and food supply, and has promoted my country's great achievements in the development of modern agriculture. However, the core and foundation of agriculture is planting. Therefore, the adjustment of the structure of the planting industry is very critical to the adjustment of the agricultural structure. As the times advance and technology develop, people are increasingly pursuing scientific planting. In exploration and practice, people have found that optimizing and adjusting the crop planting structure through local actual conditions and local actual crop planting statistics can improve the adaptability of crops and make crops more suitable for the local environment. Therefore, formulating planting plans, improving and updating them can not only meet people's daily food needs, but also bring good economic benefits to achieve sustainable agricultural development [2].

The north and south regions of the North China Plain span large latitudes, and there are obvious differences in temperature, precipitation and other conditions between north and south. Therefore, people's production activities will be affected accordingly, resulting in obvious differences in key phenological periods of crops [3]. We must take a long-term perspective on crop planting issues, not affect the subsequent growth of crops, and not damage the soil environment because of immediate benefits. Planting strategies should follow the growth laws of crops. Just as the same crop or crops of the same family cannot be continuously planted on a piece of land. In order to achieve sustainable development, keep the land healthy and suitable for crop growth, the land can be used to plant beans at least once within three years. crop. Therefore, there are many constraints in the process of formulating a reasonable planting strategy. There are many influencing factors to judge whether it is suitable for planting, and the data statistical process is complex. Therefore, it is necessary to establish a reliable model and then obtain a reasonable planting plan. It is conducive to achieving efficient and sustainable development of agriculture under the rigid constraints of the market and resources and the strategic requirements of the new food security concept, and embarking on the path of agricultural modernization with product safety, resource conservation, and environmental friendliness [4-6].

In view of the complexity of planting scenarios and the diversity of constraints in the North China Plain, and the lack of systematic data processing and intelligent algorithm support for existing planting schemes, making it difficult to achieve the optimal balance between resource utilization and profits, the research purposes of this paper are as follows: First, based on the field planting data in 2023, the expected crop sales volume is determined through the VLOOKUP function, the lowest sales price is screened, and data cleaning and standardization are completed based on planting costs to clarify the distribution characteristics of crop profits in different plots; The second is to build a functional model with the goal of maximizing total profit from 2024-2030 for the two market scenarios of "all waste of excess sales" and "sales at reduced prices for excess sales", and incorporate the plot planting cycle, continuous cropping taboos, ecological and production constraints such as bean rotation; The third is to use particle swarm optimization algorithm to solve the optimal solution through Python programming, and finally form a scientific planting strategy that adapts the characteristics of the North China Plain land and takes into account economic benefits and ecological sustainability, providing quantitative basis for optimizing local agricultural planting structure and efficient utilization of resources. Decision basis.

2 MATERIALS AND METHODS

2.1 Data

The research data were obtained through local field investigations and statistical yearbooks.

2.1.1 Expected sales volume

First, use the vlookup function to correspond the yield per mu in the 2023 planting situation table, multiply the yield per mu by the planting area to obtain the 2023 production data, and use the 2023 production as the total sales volume as the expected sales volume in the future.

2.1.2 Standardized treatment

In order to ensure accurate data analysis and simple data cleaning, python was used to type convert the crop number, convert non-numeric values into NAN, and then replace NAN with-1 to identify invalid tags. Finally, the invalid numbers were filtered. At the same time, the data is standardized to prevent the scope from being too large and causing the proportion of data to decrease and affect analysis.

2.2 Research methods

2.2.1 Research and analysis

If you want to obtain the optimal planting strategy in the future, you first need to reasonably process the expected sales volume, sales unit price, and planting cost data in 2023. Secondly, you need to formulate plans to reduce costs and reduce waste of land resources. Therefore, you need to add a small number of realistic variables. Consider (Such as the total output of crops, market sales, price fluctuations and other factors), set the objective function according to two different processing methods of remaining products, generate code according to the objective function, and finally use the optimization model to obtain the results.

2.2.2 Particle Swarm Optimization (PSO)

Particle swarm algorithm is a method of finding an optimal solution through iteration in multi-dimensional space. Particle swarm algorithm randomly gives the velocity and position of particles in the solution space, and initializes the number of particles, maximum number of iterations, inertia weights, individual learning factors and social learning factors [7]. Then evaluate the fitness of particles according to the objective function, find out the historical best position (pbest) and global best position (gbest) of particles, and then iterate, and continue to evaluate particles using the objective function. If the particle's new fitness is better than the historical fitness, update the position to the historical best position (pbest), compare the best positions of all particles again, and find a global best position (gbest) until a termination condition is encountered [8].

The iteration ends. Each potential solution is called a particle. Each particle remembers the historical best position (pbest) and shares a global best position (gbest). Each particle adjusts based on these two positions to obtain the optimal solution.

Applicable conditions are as follows:

Condition 1: Particle swarm optimization solves continuous problems, that is, decision variables can be taken within a continuous range.

Condition 2: The objective function is computable in order to find the optimal solution based on fitness.

Condition 3: Progress during the search process constantly adjusts the PSO parameters so that it does not converge prematurely due to obtaining a local optimal solution.

Condition 4: Since particle swarm optimization can store past information to predict future information, the objective function or constraint conditions can change over time.

The velocity of particle a is represented by $V_a = (v_a 1, v_a 2, ..., v_a D)$. For each iteration, its d-th dimension ($1 \le d \le D$) changes according to the following equation:

$$V_{ad}^{(t+1)} = w v_{ad}^{(t)} + c_1 r_1 \left(p_{ad} - x_{ad}^{(t)}\right) + c_1 r_2 \left(g_d - x_{ad}^{(t)}\right) \tag{1}$$

$$X_{ad}^{(t+1)} = X_{ad}^{(t)} + V_{ad}^{(t+1)} \tag{2}$$

Where w is the inertia weight, c1 and c2 are both acceleration constants, and rand () and Rand () are random numbers varying in the range of [0,1] respectively. The superscript (t) denotes the state at the t-th iteration, while (t+1) indicates the updated state after the current iteration. The original notation vid is corrected to $V_{ad}^{(t+1)}$ (updated velocity), and V_{ad} is corrected to $V_{ad}^{(t)}$ (current velocity).

3 RESULTS

3.1 Crop Profit Data Processing and Visualization Analysis

In 2023, the yield per mu of relevant data will be multiplied by the sales unit price to obtain the minimum sales amount and the maximum sales amount per mu. Then, the two sales amounts will be subtracted from the planting cost to obtain the two profits per mu. The maximum profit will be divided by the cost to obtain the maximum profit ratio. Using the pivot table, using the two profits and income ratios as values, and crop names and plots as columns to obtain new tabular data, import it into spsspro visualization, and screen out crops with poor profits., narrowing the scope of the data. The relevant results are shown in Figures 1-6.

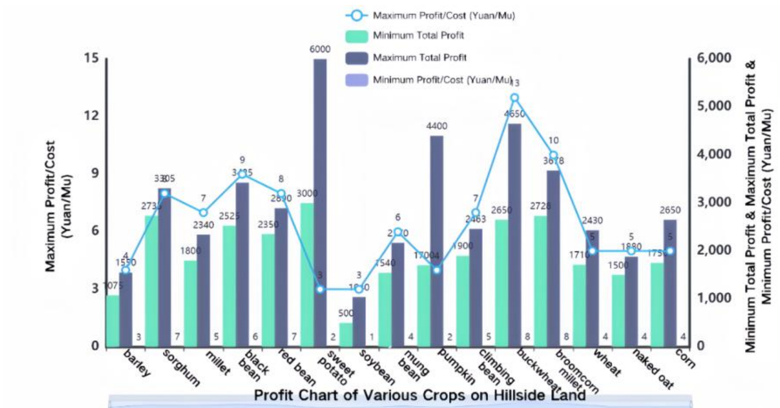

Figure 1 Profit Map of Various Crops on Hillside Land

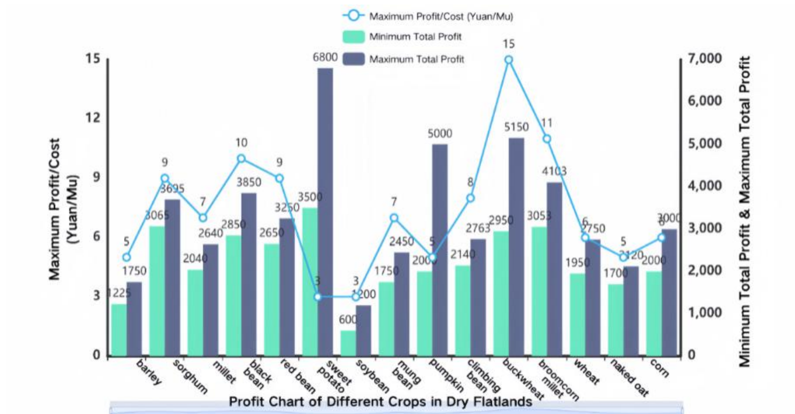

Figure 2 Profit Map of Different Crops in Dry Flatlands

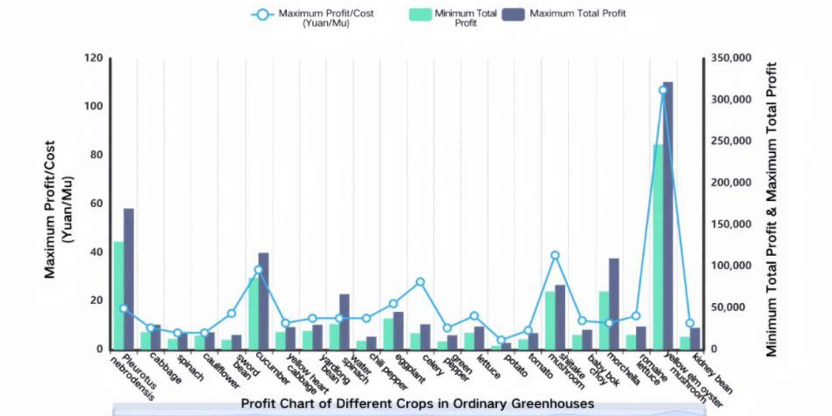

Figure 3 Profit Map of Different Crops in Ordinary Greenhouses

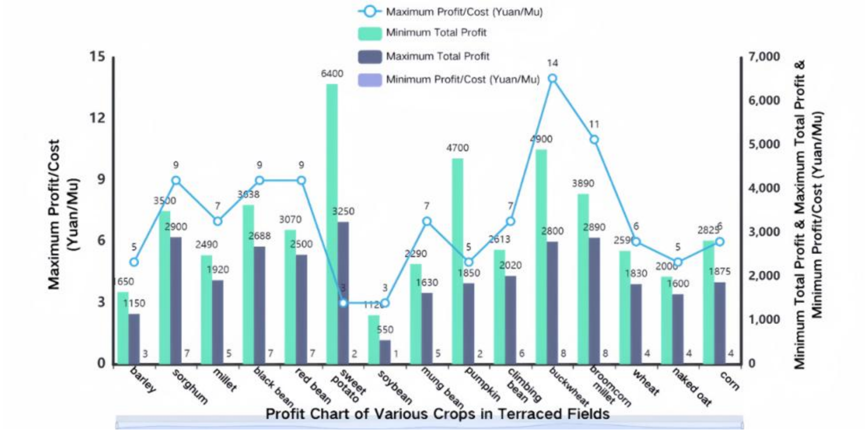

Figure 4 Profit Map of Each Crop in Terraced Fields

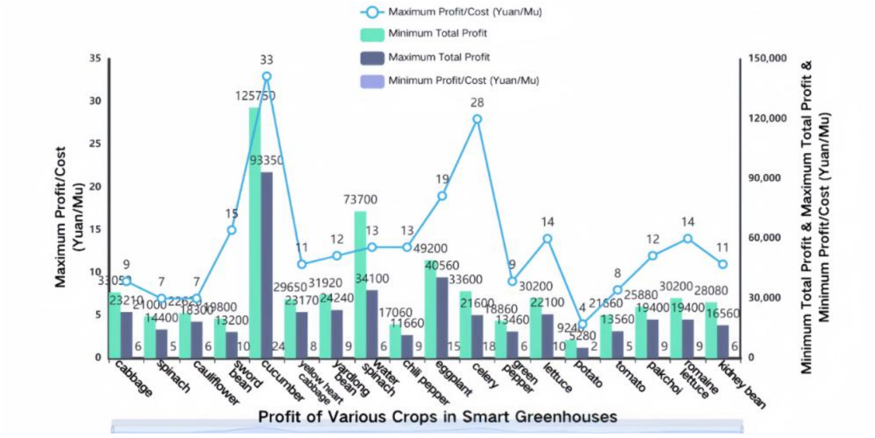

Figure 5 Profits of Various Crops in Smart Greenhouses

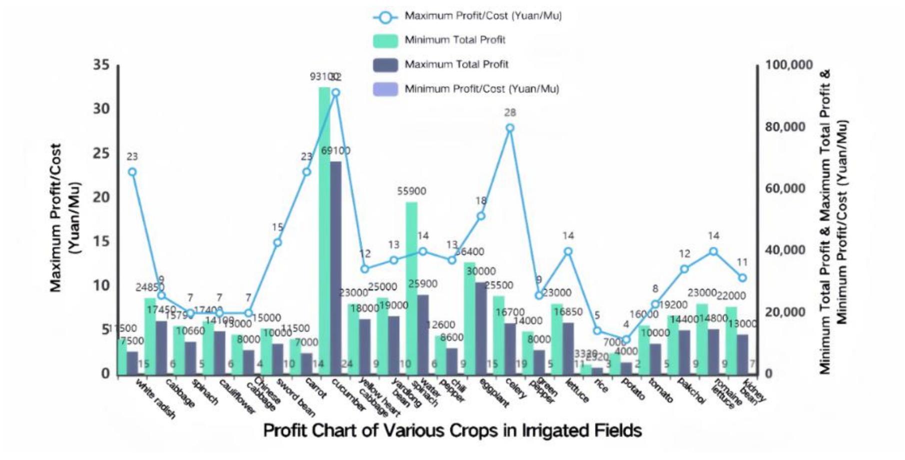

Figure 6 Profit Chart of Each Crop in Irrigated Land

Based on the statistical data from 2023 and adhering to a consistent analytical framework, this study conducted an analysis of the planting profits of different crops in various environments, including hillside land, dry flat land, ordinary greenhouses, terraced fields, smart greenhouses, and irrigated land. First, we calculated the product of crop yield per mu (a Chinese unit of area, approximately 0.067 hectares) and the selling price in each environment to determine the minimum and maximum sales revenue per mu. After deducting the costs, we derived the minimum and maximum profits as well as the maximum profit ratio. Subsequently, we used pivot tables to consolidate the data and generate new tables, which were then imported into SPSSPRO software to create profit charts.

From these charts, it is evident that there are extremely significant differences in crop profits across different environments. For instance, in smart greenhouses, the maximum total profit per mu for knife beans (a type of legume) reached 125,750 yuan, while in irrigated land, the maximum total profit per mu for carrots reached 93,100 yuan. However, some crops yielded relatively low profits. These analytical results provide crucial data references for planting management in various environments, facilitating the rational selection of crops, optimization of planting structures, maximization of planting benefits, and promotion of efficient and precise agricultural development.

3.2 Construction of Total Profit Objective Function Based on Different Sales Scenarios

In order to obtain the optimal planting strategy, the total profit from 2024-2030 is used as the objective function. Because there are many data variables, the profit of each crop in different plots during the year is first calculated. Ask for the profit of all crops for one year, and finally ask for the total profit for seven years. According to the two different conditions in the title, the objective function is constructed as follows:

Objective function 1:

$$\text{Max: } Z_1=\sum_{r=0}^{7}\sum_{f=1}^{2}\sum_{i}\left(p_i\cdot\frac{\min\left(\sum_v x_{i,v,f,r}\cdot q_i,D_i\right)}{q_i}-c_i\cdot\sum_{v}x_{i,v,f,r}\right) \tag{3}$$

Objective function 2:

$$\text{Max: } Z_2=\sum_{r=0}^{7}\sum_{f=1}^{2}\sum_{i}\left(p_i\cdot\frac{\min\left(\sum_\text{h} x_{i,v,f,r}\cdot q_i,D_i\right)}{q_i}+p_i^{'}\cdot\frac{\max\left(\sum_\text{h} x_{i,v,f,r}\cdot q_i-D_i,0\right)}{q_i}-c_i\cdot\sum_{b}x_{i,v,f,r}\right) \tag{4}$$

Among them, Z_1 and Z_2 represent the maximum profits, p_i represents the selling price per mu of the i-th crop, q_i is the kilogram yield per mu of the i-th crop, D_i represents the expected kilogram sales of the i-th crop, and c_i is the planting cost per mu of the i-th crop.

The decision variable is: $x_{i,b,f,r}$, which represents the area (unit: mu) of the i-th crop planted on the h-th plot or greenhouse in the f-th quarter in the r-th year.

3.3 The Implementation of Particle Swarm Optimization Algorithm with Integrated Planting Constraints

Add constraints: Among them, crop type M_i: represents the type of crop i (such as grain, grain (bean), vegetable, vegetable (bean), edible fungus). Plot type L_h: Represents the type of plot h (such as flat dry land, terraced fields, sloping land, irrigated land, ordinary greenhouses, smart greenhouses).

(1) For "ordinary greenhouses" (L_v=L_5), one season of vegetables and one season of edible fungi are planted each year, and the area of the vegetable and edible fungi planting does not exceed the total area of all plot types.

$$\sum_{i\in\{i\mid M_i=M_3\}}x_{i,v,1,r}+\sum_{i\in\{i\mid M_i=M_5\}}x_{i,v,2,r}\le A_v,\ \forall v\text{ with }L_v=L_5,r\in\{0,1,2,3,4,5,6,7\} \tag{5}$$

(2) For "Smart greenhouses" (L_v=L_6), two vegetable planting cycles can be achieved each year:

$$\sum_{i\in\{i\mid M_i=M_3\}}x_{i,v,f,r}\le A_v,\ \forall v\text{ with }L_v=L_6,f\in\{1,2\},r\in\{0,1,2,3,4,5,6,7\} \tag{6}$$

(3) The same crop cannot be continuously planted on the same plot of land.

$$x_{i,v,f,r}\cdot\ x_{i,v,f,r+1}=0,\ \forall i,v,f\in\{1,2\},r\in\{0,1,2,3,4,5,6,7\} \tag{7}$$

(4) Dry land, terraced fields and sloping land complete one crop cycle each year:

$$\sum_{f=1}^{2}\sum_{i}x_{i,v,k,r}\le A_v,\ \forall v\text{ with }L_v\in\{L_1,L_2,L_3\},\forall r \tag{8}$$

(5) The irrigated land can be grown with water straw in a single season or with rice straw crops in two seasons each year:

$$\begin{gathered}x_{i,v,1,r}+x_{i,v,2,r}\le A_v,\ \forall v\text{ with }L_v=L_4,\forall i\text{ with }M_i=M_1,i=C_{16},\forall r\\ \sum_{i\in\{i\mid M_i\in\{M_3,M_4\}\}}x_{i,v,2,r}\le A_v\cdot\ b_{v,r},\ \forall v\text{ with }L_v=L_4,\forall r\end{gathered} \tag{9}$$

Finally, the solution matrix is obtained through Python using particle swarm optimization algorithm.

4 CONCLUSIONS

Focusing on the goals of efficient utilization of cultivated land resources and sustainable agricultural development in the North China Plain, this study forms a complete set of optimization plans for crop planting strategies through data processing, model construction and intelligent algorithm solution: first based on 2023 field data, VLOOKUP function, data standardization and visualization analysis to clarify the distribution of crop profits and the range of high-quality crops; An objective function is then constructed for two residual product processing scenarios, combined with constraints such as plot characteristics (such as "vegetable + edible fungus" rotation in ordinary greenhouses, double-season vegetable planting in smart greenhouses), continuous cropping taboos, and rotation requirements, and accurately solved with the help of particle swarm optimization algorithm. The optimal planting plan from 2024 to 2030 effectively achieves a balance between maximizing profits and minimizing resource waste, while taking into account soil health and ecological sustainability. In the future, the research dimension can be further expanded to include variables such as the impact of climate change on crop yields, dynamic fluctuations in market prices, and adaptability of new crop varieties, optimize the inertia weights and learning factor parameters of the particle swarm optimization algorithm, and improve the adaptability of the model to complex agricultural scenarios.; GIS geospatial analysis technology can also be combined to refine planting strategies at different latitudes and climate zones, promote the popularization and application of research results to larger areas, and provide more comprehensive technical support for modern agricultural precision planting.

COMPETING INTERESTS

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

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