# Optimization Research on Rural Crop Planting Strategies Based on Greedy Algorithm and PSO

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**Abstract.** As the crop market continues to expand and national policies support sustainable rural development, it is increasingly important to safeguard farmers' interests and crop cultivation. In order to help a rural village develop a planting strategy for the next 7 years according to the local conditions, this paper preprocesses the crop production and planting area based on the data of a village in 2023, and calculates and visualizes its future sales volume. After that, a single-objective optimization model is established to plan the planting strategy for the next 7 years, considering two scenarios: over-selling is regarded as stagnant selling or selling at 50% price reduction of the original price, and setting up the corresponding objective function and constraints. In this paper, the greedy algorithm is firstly used to solve the problem step by step, based on the optimal solution of the previous year to obtain the optimal solution of the next year as much as possible, aiming to maximize the profit of the next seven years. However, the analysis and discussion show that the greedy algorithm is only a local optimum. Therefore, this paper further adopts the particle swarm algorithm to optimize the model and re-solve to obtain a better solution as the final planting strategy.

**Keywords:** Single-objective optimization models, Greedy algorithms, PSO.

## 1. Introduction

With advancements in agricultural technology and the increasing pursuit of healthy diets, China's vegetable consumption market is experiencing robust growth and vitality [1]. And because of the continued expansion of crop markets and national policy support for sustainable rural development, it is increasingly important to safeguard farmers' interests and crop cultivation. However, under conditions of limited arable land, a key challenge facing the agricultural industry is how to develop the vegetable planting sector based on local conditions, align it effectively with market demand, and ensure a safe, high-quality, and stable supply of vegetables [2].

Zhang Zhaotong et al. [3] proposed a crop production decision model based on a greedy algorithm, which aims at maximizing economic benefits while considering factors such as risk and crop rotation, yielding an optimal production decision combination. However, the greedy algorithm is limited to locally optimal solutions and the results obtained are not optimal in the face of global. In contrast, PSO performs better than the greedy algorithm in finding globally optimal solutions.Cui Hao [4] introduced a fresh vegetable sales forecasting model based on the Particle Swarm Optimization (PSO) algorithm, utilizing the advantages of PSO in optimizing neural network hyperparameters, and proposed a sales forecasting method based on a CNN-PSO-LSTM model. Additionally, Ye Lu et al. [5] developed a vegetable price forecasting model using PSO, establishing a vegetable price combination forecast model based on PSO-optimized BP neural networks, which has shown promising application results.

Due to the unique terrain and planting requirements of a village in North China, and to account for planting risks [6], planning a crop planting strategy for the years 2024 to 2030 is a complex yet critical task. This paper first employs a greedy strategy to solve the single-objective optimization model established here; recognizing this provides only a local optimum, apply PSO to further optimize the model. The final results meet constraints and maximize profit.

## 2. The basic establishment and solution of model

### 2.1. Data Preprocessing and Visualization

Data from: https://www.mcm.edu.cn/html_cn/node/a0c1fb5c31d43551f08cd8ad16870444.html.

According to the title, this paper assumes that the expected sales volume, planting cost, acreage and sales price of various crops in the next seven years in the village are equal to those in 2023, and also by observing the data in 2023, we can know that the sales unit price of each crop is interval-type data, so we process the data on the sales unit price.

Step1: Data Preprocessing

For the village's crop planting strategy planning, this paper adopts reasonable simplification measures to cope with the volatility of market prices In view of the dynamic changes in market supply and demand is difficult to accurately predict, and the main objective of this paper is to develop crop planting strategies rather than direct intervention in market prices, therefore, this paper chooses to take the average of the highest and lowest values of the unit price of sales as the target unit price of crops, for the target unit price of sales of some of the displays in Table 1.

This approach is designed to simulate the “average” market conditions under which the crop is sold, and thus provide a relatively robust baseline for evaluating the potential returns under different cropping strategies. It is argued that by using average prices, it is possible to focus more on optimizing the cropping structure, with the aim of achieving more stable profit expectations in most cases, and based on this trend, to develop more realistic and actionable cropping plans.

**Table 1.** Sale price per unit for example

| Crop names | Sale price per unit | Measurement units |
|---|---|---|
| Soybean | 3.25 | Yuan per jin |
| Black bean | 7.25 | Yuan per jin |
| Mung bean | 7.00 | Yuan per jin |
| Wheat | 3.50 | Yuan per jin |
| Crawling bean | 6.75 | Yuan per jin |
| Corn | 3.00 | Yuan per jin |
| Pumpkin | 1.50 | Yuan per jin |
| Potato | 3.75 | Yuan per jin |

Step2: Visual Analysis

After analyzing that the village plot types cover a wide range of types such as flat and dry land, terraced land, hillside land, watered land, ordinary greenhouses and smart greenhouses, and there are significant differences in the area of different plots, reflecting the complexity of the agricultural production environment and can profoundly affect the local agricultural yield, this paper will calculate the corresponding 2023 crop yields in Figure 2 below.

The actual production of some crops in 2023 is shown in Figure 1.

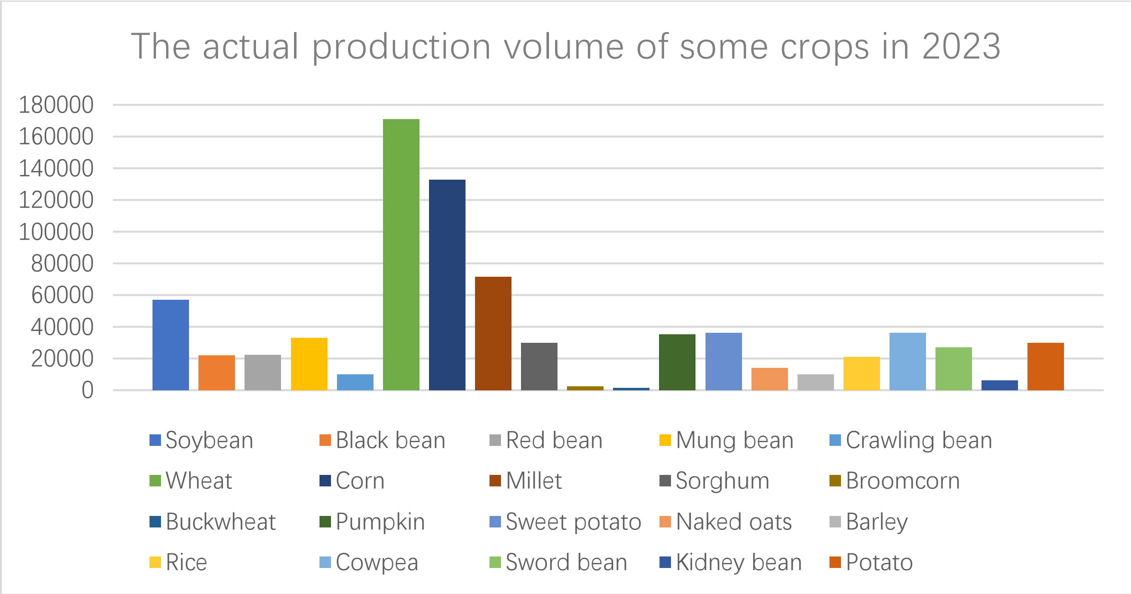


**Figure 1.** Actual production of some crops in 2023

Figure 1 provides insight into the distinctive features of agricultural production in the region. Among the grain crops produced in the region, wheat and corn yields are significantly higher, while corn and buckwheat yields are significantly lower in comparison. This phenomenon is mainly attributed to the unique climatic conditions of North China, its relatively humid climate is particularly suitable for the growth of wheat and corn and other crops. At the same time, because of the close correlation between market demand and planting efficiency, wheat and corn naturally become the staple food on the table of the people in the region, the market demand continues to be strong, and the expected sales continue to go up, which further promotes the large-scale planting and production of these two crops, thus realizing the effective docking of agricultural production and market demand.

### 2.2. Building an optimization model to solve for profit cost

This paper establishes an optimization class model based on the crops planted in the village in 2023, and solves the planting strategy of the village in the next seven years under two scenarios.

Step1: Determine the decision variables

In this paper, the question needs to determine the crop planting area and constrain the planting of grain, vegetables and fungus, so introduce decision variables: $x_{ijk}$ (Area planted with the kth crop on the jth plot of land in year i)

Step2: Finding Constraints

(1) Crop land constraints

The 0-1 variable is set to constrain the planting of crop types, which is denoted as 1 if the jth plot in year i is able to plant the kth crop, and 0 if the jth crop cannot be planted .

Constraints for crop land constraints: $l_{ijk}$ $(i=1,2,\ldots,7;\ j=1,2,\ldots,54;\ k=1,2,\ldots,41)$

(2) Planting time constraints

Since some plots can only be planted in a single season and some plots can be planted in two seasons, two 0-1 variables are set to constrain the planting in the first and second seasons. i denotes the ith year in the future, j denotes the jth plot, and k denotes the planting of the kth crop, and the variable is denoted as 1 if the crop is planted on the site in the current year's quarter, and as 0 otherwise.

Planting constraints for the first season: $t_{ijk}(i=1,2,\ldots,7;\ j=1,2,\ldots,54;\ k=1,2,\ldots,41)$

Planting constraints for the second season: $u_{ijk}(i=1,2,\ldots,7;\ j=1,2,\ldots,54;\ k=1,2,\ldots,41)$

For part of the land it is considered to be planted in the first season:

$u_{ijk}=0(j=1,2,\ldots,26;k=1,2,\ldots,15)$

Seasonal planting restrictions for vegetable crops (except cabbage and carrots):

$u_{ijk}=0(j=27,\ldots,50;k=17,\ldots,34)$

For cabbage and red or white carrots can only be planted in watered fields second season:
$t_{ijk}$=0(j=27, …,34;k=35,…,37)

For edible mushrooms can only be grown in ordinary greenhouses second season:
$t_{ijk}$=0(j=35, …,50;k=38,…,41)

For the rest of the unconstrained $t_{ijk}$ and $u_{ijk}$, let them be 0 or 1.

(3) Planting constraints

Flat drylands, terraces and slopes are suitable for growing one season of food crops per year(j=1,2…, 26):

$$\sum_{k=1}^{15} l_{ijk} \cdot t_{ijk} \cdot x_{ijk} \le S_{\mathrm{j}} \tag{1}$$

Irrigated lands are suitable for growing one season of rice or two seasons of vegetables per year(j=27…, 34):

$$\sum_{k=16}^{16} l_{ijk} \cdot t_{ijk} \cdot x_{ijk} \le S_{\mathrm{j}} \parallel (\sum_{k=17}^{34} l_{ijk} \cdot t_{ijk} \cdot x_{ijk} \le S_j \&\& \sum_{k=35}^{37} l_{ijk} \cdot u_{ijk} \cdot x_{ijk} \le S_{\mathrm{j}}) \tag{2}$$

Ordinary greenhouses are suitable for growing one season of vegetables and one season of edible mushrooms per year(j=35…, 50):

$$\sum_{k=17}^{34} l_{ijk} \cdot t_{ijk} \cdot x_{ijk} \le S_i \;\; \&\& \;\; \sum_{k=38}^{41} l_{ijk} \cdot u_{ijk} \cdot x_{ijk} \le S_i \tag{3}$$

Smart greenhouses are suitable for growing two seasons of vegetables per year(j=51…, 54):

$$\sum_{k=17}^{34} l_{ijk} \cdot t_{ijk} \cdot x_{ijk} \le S_i \quad \&\& \; \sum_{k=17}^{34} l_{ijk} \cdot u_{ijk} \cdot x_{ijk} \le S_i \tag{4}$$

(4) Cannot re-crop constraints

Since the definition of heavy cropping may be different for each crop, in this paper heavy cropping is defined as not being able to grow each crop consecutively in the same field, and a crop can be grown only once in two seasons in the same year, according to most crops.

$$if\ u_{ijk} = 1 \ \begin{cases} t_{ijk} + \mathrm{u}_{ijk} \le 1 \\ u_{ijk} + t_{(i+1)jk} \le 1 \end{cases} \tag{5}$$

$$if\ u_{ijk} = 0 \ \begin{cases} t_{ijk} \le 1 \\ t_{ijk} + t_{(i+1)jk} \le 1 \end{cases} \tag{6}$$

(5) Bean planting constraints

From the question, it is clear that each plot needs to be planted with soybean crop at least once in three years from 2023. So list out formula based on the question:

$$\sum_{i}^{i+2} t_{ijk} + u_{ijk} \ge 1(\mathrm{i}=1,2,\ldots,5;\ \mathrm{j}=1,2,\ldots,54;\mathrm{k}=1,2,\ldots,5,17,18,19) \tag{7}$$

(6) Planting area constraints

From the question, it can be seen that each crop in a single plot (including greenhouses) planting area should not be too small, so set the ratio coefficient k = 0.2, so that each crop planted in each piece of land planting area is greater than one-fifth of the land.

$$kS_j \le x_{ijk} \le S_j \tag{8}$$

Step3: Determine the objective function

Calculating the profit of the village for each of the next seven years on the above basis, the case one objective function is:

$$max \sum_{i=1}^{7} \sum_{j=1}^{54} \sum_{k=1}^{41} \{(min(x_{ijk} \cdot b_{ijk}, y_{ijk}) \cdot d_{ijk} - x_{ijk} \cdot c_{ijk}) \cdot l_{ijk} \cdot (t_{ijk} + u_{ijk})\} \tag{9}$$

The case two objective function is:

$$max\sum_{i=1}^{7}\sum_{j=1}^{54}\sum_{k=1}^{41}\{(min(x_{ijk}\cdot b_{ijk},y_{ijk})\cdot d_{ijk}-x_{ijk}\cdot c_{ijk}+0.5\times max(x_{ijk}\cdot b_{ijk}-y_{ijk},0)\cdot d_{ijk})\cdot l_{ijk}\cdot(t_{ijk}+u_{ijk})\} \tag{10}$$

$b_{ijk}$、$y_{ijk}$、$d_{ijk}$、$c_{ijk}$are the acreage, expected sales volume, unit sales price, and cost per acre of the kth crop planted in the jth plot in year i, respectively.

$y_{ijk}=b_{ijk}\cdot x_{0jk}$ $x_{0jk}$ refers to the acreage of the jth plot planted with the kth crop in the year 2023.

Step4: Integrated Optimization Model

(1) If the total production of a crop per season exceeds the corresponding expected sales, the excess is not marketed, resulting in a waste.

$$max\sum_{i=1}^{7}\sum_{j=1}^{54}\sum_{k=1}^{41}\{(min(x_{ijk}\cdot b_{ijk},y_{ijk})\cdot d_{ijk}-x_{ijk}\cdot c_{ijk})\cdot l_{ijk}\cdot(t_{ijk}+u_{ijk})\} \tag{11}$$

$$s.t.\begin{cases}\sum_{i}^{i+2}t_{ijk}+u_{ijk}\geq 1\ (i=1,2,\dots,5;\ j=1,2,\dots,54;k=1,2,\dots,5,17,18,19)\\ \sum_{k=1}^{15}l_{ijk}\cdot t_{ijk}\cdot x_{ijk}\leq S_j\ (j=1,2\dots,\ 26)\\ \sum_{k=16}^{16}l_{ijk}\cdot t_{ijk}\cdot x_{ijk}\leq S_j\ ||\ (\sum_{k=17}^{34}l_{ijk}\cdot t_{ijk}\cdot x_{ijk}\leq S_j \quad \sum_{k=35}^{37}l_{ijk}\cdot u_{ijk}\cdot x_{ijk}\leq S_j)\ (j=27\dots,\ 34)\\ \sum_{k=17}^{34}l_{ijk}\cdot t_{ijk}\cdot x_{ijk}\leq S_i \quad \sum_{k=38}^{41}l_{ijk}\cdot u_{ijk}\cdot x_{ijk}\leq S_i\ (j=35\dots,\ 50)\\ \sum_{k=17}^{34}l_{ijk}\cdot t_{ijk}\cdot x_{ijk}\leq S_i \quad \sum_{k=17}^{34}l_{ijk}\cdot u_{ijk}\cdot x_{ijk}\leq S_i\ (j=51\dots,\ 54)\\ kS_j\leq x_{ijk}\leq S_j\ (i=1,2,\dots,5;\ j=1,2,\dots,54;\ k=1,2,\dots,5,17,18,19)\\ if\ u_{ijk}=1\ \begin{cases}t_{ijk}+u_{ijk}\leq 1\\ u_{ijk}+t_{(i+1)jk}\leq 1\end{cases}\\ if\ u_{ijk}=0\ \begin{cases}t_{ijk}\leq 1\\ t_{ijk}+t_{(i+1)jk}\leq 1\end{cases}\end{cases} \tag{12}$$

(2) If the total production of a crop per season exceeds the corresponding expected sales volume, the excess is sold at a reduced price of 50% of the 2023 sales price.

$$max\sum_{i=1}^{7}\sum_{j=1}^{54}\sum_{k=1}^{41}\{(min(x_{ijk}\cdot b_{ijk},y_{ijk})\cdot d_{ijk}-x_{ijk}\cdot c_{ijk}+0.5\times max(x_{ijk}\cdot b_{ijk}-y_{ijk},0)\cdot d_{ijk})\cdot l_{ijk}\cdot(t_{ijk}+u_{ijk})\} \tag{13}$$

$$s.t.\begin{cases}\sum_{i}^{i+2}t_{ijk}+u_{ijk}\geq 1\ (i=1,2,\dots,5;\ j=1,2,\dots,54;k=1,2,\dots,5,17,18,19)\\ \sum_{k=1}^{15}l_{ijk}\cdot t_{ijk}\cdot x_{ijk}\leq S_j\ (j=1,2\dots,\ 26)\\ \sum_{k=16}^{16}l_{ijk}\cdot t_{ijk}\cdot x_{ijk}\leq S_j\ ||\ (\sum_{k=17}^{34}l_{ijk}\cdot t_{ijk}\cdot x_{ijk}\leq S_j \quad \sum_{k=35}^{37}l_{ijk}\cdot u_{ijk}\cdot x_{ijk}\leq S_j)\ (j=27\dots,\ 34)\\ \sum_{k=17}^{34}l_{ijk}\cdot t_{ijk}\cdot x_{ijk}\leq S_i \quad \sum_{k=38}^{41}l_{ijk}\cdot u_{ijk}\cdot x_{ijk}\leq S_i\ (j=35\dots,\ 50)\\ \sum_{k=17}^{34}l_{ijk}\cdot t_{ijk}\cdot x_{ijk}\leq S_i \quad \sum_{k=17}^{34}l_{ijk}\cdot u_{ijk}\cdot x_{ijk}\leq S_i\ (j=51\dots,\ 54)\\ kS_j\leq x_{ijk}\leq S_j\ (i=1,2,\dots,5;\ j=1,2,\dots,54;\ k=1,2,\dots,5,17,18,19)\\ if\ u_{ijk}=1\ \begin{cases}t_{ijk}+u_{ijk}\leq 1\\ u_{ijk}+t_{(i+1)jk}\leq 1\end{cases}\\ if\ u_{ijk}=0\ \begin{cases}t_{ijk}\leq 1\\ t_{ijk}+t_{(i+1)jk}\leq 1\end{cases}\end{cases} \tag{14}$$

# 3. Results

## 3.1. The establishment of simulation model

Step1: Solving Single-Objective Optimization Models Using the Greedy Algorithm

In this paper, the greedy algorithm is used to solve the single-objective optimization model established by the above process, which is gradually optimized by solving its maximum value year by year to finally reach the optimal solution for the next 7 years.

The greedy algorithm is a strategic algorithm that aims to obtain a locally optimal solution in each step of the selection [7]. This selection strategy needs to satisfy the no a posteriori condition, meaning that the previous decision-making process does not have an impact on the subsequent state and is only closely related to the current state [8].

(1) Solve for the 2024 planting strategy and maximum profit based on the 2023 planting on top of the underlying constraints.

(2) Based on the planting strategy in 2024, continue to solve the optimal planting strategy and maximum profit in 2025 based on the above constraints and superimpose them.

(3) Repeat until the planting strategy for 2030 is solved and filled into the table to give the maximum profit.

Step2: Reflections on the greed model

The use of greedy algorithm can be faster to solve the corresponding planting strategy plan and profit, but considering the greedy algorithm can only seek the local optimal solution [9], and the results of the review found that there are some plots of planting dissatisfaction, so based on the idea of seeking a more optimal solution, this paper will be the following particle swarm optimization algorithm to take the single-objective optimization model for the global optimality of the solution.

Step3: PSO Solution

In order to ensure the accuracy of the requested single objective optimization, this paper will use the particle swarm algorithm to get the optimal solution to optimize the results of the greedy requested above. Particle swarm algorithm is the basic idea of particle swarm algorithm is to find the optimal solution through collaboration and information sharing between individuals in the group. In the algorithm, each solution of the optimization problem is regarded as a “particle” in the search space, and all particles follow certain rules to move in the solution space, update their speed and position through iteration, and finally find the optimal solution of the problem [10].

Initialization parameters: the inertia weight was set to 0.5, both the individual learning factor and the social learning factor were set to 1.5, the number of particles was set to 30, and the maximum number of iterations was set to 2000.

Initialization of particle positions and velocities: the positions and velocities of the particles are initialized by random generation, and the positions indicate the proportion of each crop planted in each plot, in each season, and in each year.

Particle velocity and position update: The basic PSO velocity update formula is used to update the velocity and position of particles in each iteration based on the individual best position and the global best position. The updated particle positions are restricted to non-negative values.

Convergence and visualization: plot the convergence curve after 2000 iterations and output the optimal policy.

Step4: PSO algorithm results are shown in Figure 2.

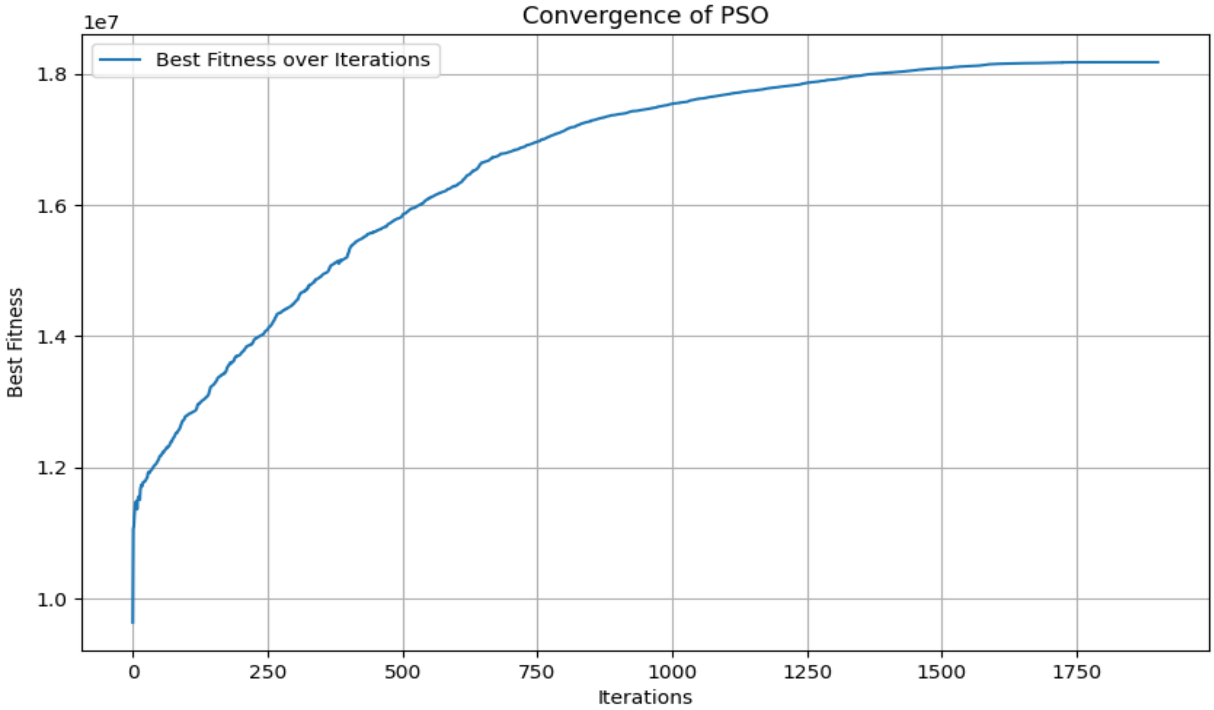


**Figure 2.** Convergence curve of particle swarm optimization

Since the convergence curves of the particle swarm algorithm in the first and second query are roughly similar, this paper only shows the convergence curve of the first query here.

### 3.2. Analysis of experimental results

By solving the algorithm above, this paper derives the planting strategies for the two scenarios and the corresponding production returns for the next seven years, and the following two tables will show some of the planting strategies for scenarios one and two, respectively.

Scenario 1 is shown in Table 2.

**Table 2.** Parts of Planting strategies for scenario 1 in 2024

| LOT | CROP | YEAR | AREA | QUARTER |
|---|---|---|---|---|
| Lot 1 | Soybean | 2028 | 0 | first quarter |
| Lot 1 | Soybean | 2029 | 0 | first quarter |
| Lot 1 | Soybean | 2030 | 40.6 | first quarter |
| …… | …… | …… | …… | …… |
| Lot 54 | Eggplant | 2027 | 0.6 | second quarter |
| Lot 54 | Eggplant | 2028 | 0.6 | second quarter |
| Lot 54 | Eggplant | 2029 | 0.6 | second quarter |
| Lot 54 | Eggplant | 2030 | 0.6 | second quarter |

Scenario 2 is shown in Table 3

**Table 3.** Parts of Planting strategies for scenario 2 in 2024

| LOT | CROP | YEAR | AREA | QUARTER |
|---|---|---|---|---|
| Lot 1 | Soybean | 2028 | 0 | first quarter |
| Lot 1 | Soybean | 2029 | 0 | first quarter |
| Lot 1 | Soybean | 2030 | 38.2 | first quarter |
| …… | …… | …… | …… | …… |
| Lot 54 | Eggplant | 2027 | 0.6 | second quarter |
| Lot 54 | Eggplant | 2028 | 0.6 | second quarter |
| Lot 54 | Eggplant | 2029 | 0.6 | second quarter |
| Lot 54 | Eggplant | 2030 | 0.6 | second quarter |

The results show that Scenario 1 and Scenario 2 yield maximum profits of 30,964,490 yuan and 35,834,720 yuan, respectively, over the next seven years. This outperforms the greedy strategy, demonstrating the particle swarm algorithm's ability to find superior solutions and higher profits.

## 4. Conclusions

After an in-depth analysis of the results, this paper finds that for treatment choices faced with exceeding expected sales, a fifty percent price reduction sale in Case 2 would have performed superior to the expected maximum profit of the stagnant treatment in Case 1, and would have resulted in a maximum profit of five million dollars more than in Case 1, which is also more realistic.

It is worth noting that despite the different sales strategies, this paper did not observe significant changes in planting strategies by scrutinizing the data in the table through detailed observations. Specifically, only a few plots on which the types of crops planted were adjusted would have changed, while the types of crops on most plots remained the same, with only minor adjustments in planting ratios. This observation further confirms that responding to the crop portion that exceeds the market demand by flexibly adjusting the crop planting ratio is a practical strategy. It not only avoids wasting resources, but also effectively adapts to market changes. In the future, more precise planting plans will be developed to help the village, taking into account the impact of environmental factors and the actual changes in market demand from year to year.

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