Study on Crop Planting Optimization Based on Genetic Algorithm and Monte Carlo Method

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Abstract. In the context of limited global land resources, the optimization of crop planting scheme through genetic algorithm and Monte Carlo method can effectively improve the efficiency of agricultural production and resource utilization. Specifically, this study starts from the relevant data of crops in 2023, determines the selling unit price of each crop by using the principle of normal distribution, and after that, takes profit maximization as the objective function, combines the requirements of crop planting, growth pattern, actual conditions and the reality of easy cultivation and management as the constraints and introduces the penalty term to establish the optimization model, and finally uses the Monte Carlo algorithm to determine the original samples and the optimal planting scheme from 2024 to 2030 was studied by genetic algorithm. Finally the seven-year net profit was obtained for different sales programs as 19,869,900 Yuan as well as 30,917,600 Yuan respectively. It shows that selling at half price when stagnant can bring higher benefits to farmers.

Keywords: Genetic Algorithm, Monte Carlo Algorithm, 3σ Formula, Penalty Term.

1. Introduction

As the global population continues to grow and agricultural land is limited, how to maximize the benefits of crop cultivation on limited land resources has become a key issue in the field of agricultural production. In this context, optimizing crop planting plan can not only improve the economic benefits of agricultural production, but also effectively reduce the planting risk, improve the yield and efficiency, simplify the field management, reduce the planting risk due to environmental changes, and thus promote the sustainable development of rural economy. Most of the traditional planting planning methods rely on empirical or linear planning models, which are often difficult to cope with complex multi-objective problems in practical applications. In recent years, with the rapid development of computational technology and algorithm research, optimization methods such as genetic algorithm and Monte Carlo method have received widespread attention in the field of agriculture. Genetic algorithms search for the optimal solution or near-optimal solution of a problem by simulating the Darwinian natural selection and genetic mechanism and the principle of genetics in the process of biological evolution in nature, and iteratively updating the solution of the problem. It can effectively solve large-scale optimization problems. And Monte Carlo method through random sampling and simulation, randomly generated samples, with the increase in the number of simulations, thus improving the accuracy of the system results. Monte Carlo method is combined with genetic algorithm, using Monte Carlo method for random sampling to provide the genetic algorithm with original samples more in line with the natural simulation environment, thus improving the accuracy of the results.

In this study, firstly, the data on crop cultivation and related statistics for the year 2023 were processed, and the data on crop cultivation and related statistics for the year 2023 were processed to find out the total sales of each crop in the year 2023, which will serve as the expected sales of crops for each year thereafter. After that, the land was categorized according to the types of crops that can be grown on each type of land, and the various variables needed to solve this study were also determined. The sales volume, sales unit price, etc. are expressed based on the identified variables to obtain the objective function. After that, the constraints of the objective function are determined based on the requirements of various natural environments as well as growing conditions, thus determining the mathematical model for this study. Finally, the initial population was determined by Monte Carlo method and the established model was solved using genetic algorithm to obtain the optimal planting scheme from 2024 to 2030.

2. Data sources and crop data preprocessing

Data for this study was obtained from www.mcm.edu.cn.

Firstly, the crop cultivation in 2023 in the relevant dataset in the official website is divided by plot type, and the crop numbers are one-to-one correspondence with the relevant data in the 2023 statistics. From the data given in the official website, it can be seen that not all crops will be planted in the same plot type, and Figure 1 shows the number of crop types planted in different plot types in 2023. Therefore, in order to find out the total number of crops planted in different plot types, it is necessary to filter the data related to the 2023 statistics and eliminate the crops that were not planted in 2023. The use of Excel functions, the same plot type of crops planted in the planting area for the sum, and each crop with the acreage of production multiplied by the total production of each crop in the same plot type. The total production of each crop in 2023, i.e., the expected sales volume of each crop from 2024 to 2030, is obtained by using the summation function in Excel.

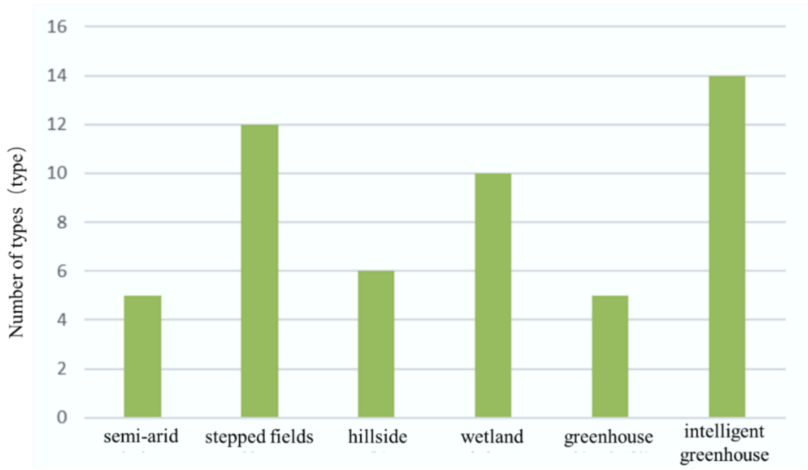

Figure 1. Number of types of crops grown in different plot types in 2023

3. Variable definition and objective function design

3.1. Identification of variables

For the establishment of variables in this study, according to the data in the official website, it can be found that semi-arid, stepped fields and hillside land can only be planted with food crops in a single season each year, while wetland, greenhouses and intelligent greenhouses have the option of planting the corresponding crops in two seasons each year, so it is possible to categorize the six cultivated land types in the problem into two main groups, one for semi-arid, stepped fields and hillside land, and the other for wetland, greenhouses with intelligent greenhouses.

Therefore, the individual variables shown in the table below were created to facilitate the modeling of the correlation.

Table 1. Variables present in the optimization model

<table>
<tr><th colspan="2">Cropland type</th><th>variable matrix</th><th>mu yield</th><th>Plot area</th><th>cost of cultivation</th><th>unit price of goods sold</th><th>expected sales volume</th></tr>
<tr><td rowspan="3">first type</td><td>semi-arid</td><td rowspan="3">$X=\begin{pmatrix} x_{11t} & \cdots & x_{1jt} \\ \vdots & \ddots & \vdots \\ x_{i1t} & \cdots & x_{ijt} \end{pmatrix}$</td><td rowspan="3">$A=\begin{pmatrix} a_{11} & \cdots & a_{1j} \\ \vdots & \ddots & \vdots \\ a_{j1} & \cdots & a_{ij} \end{pmatrix}$</td><td rowspan="3">$s_i^{(1)}$</td><td rowspan="3">$p_{ij}^{(1)}$</td><td rowspan="3">$q_{ij}^{(1)}$</td><td rowspan="3">$r_j^{(1)}$</td></tr>
<tr><td>stepped fields</td></tr>
<tr><td>hillside</td></tr>
<tr><td rowspan="3">Second type</td><td>wetland</td><td rowspan="3">$Y=\begin{pmatrix} y_{11t} & \cdots & y_{1jt} \\ \vdots & \ddots & \vdots \\ y_{i1t} & \cdots & y_{ijt} \end{pmatrix}$</td><td rowspan="3">$B=\begin{pmatrix} b_{11} & \cdots & b_{1j} \\ \vdots & \ddots & \vdots \\ b_{i1} & \cdots & b_{ij} \end{pmatrix}$</td><td rowspan="3">$s_i^{(2)}$</td><td rowspan="3">$p_{ij}^{(2)}$</td><td rowspan="2">$q_{ij}^{(2)}$</td><td rowspan="3">$r_j^{(2)}$</td></tr>
<tr><td>greenhouse</td></tr>
<tr><td>intelligent greenhouse</td><td></td></tr>
</table>

Table 1 lists the variables used in the model for this study, where matrix X and matrix A correspond to the first type of cropland and matrix Y and matrix B correspond to the second type of cropland. i represents the i th cropland in a particular cropland type, and j represents the crop with crop number j. $s_i^{(1)}, p_{ij}^{(1)}, q_{ij}^{(1)}, r_j^{(1)}$ are the plot area, cost of cultivation, unit price of sold goods and expected sales volume for the first cropland type, and $s_i^{(2)}, p_{ij}^{(2)}, q_{ij}^{(2)}, r_j^{(2)}$ are the plot area, cost of cultivation, unit price of sold goods and expected sales volume for the second cropland type, respectively.

Since the first type of cropland type can only grow food crops in a single season every year, in the first type of cropland type, t represents the t th year after 2023, so $t=1,2,\cdots,6,7$. While the second type of cropland type has the option to grow the corresponding crops in two seasons every year, so in the second type of cropland type, t represents season t after 2023, so $t=1,2,\cdots,13,14$. In order to investigate the impact of the treatment of the portion of total crop production exceeding the corresponding expected sales volume on farmers' cultivation from multiple perspectives, this study sets two scenarios as follows: Scenario 1: the portion exceeding the expected sales volume is not sold, resulting in wastage; and Scenario 2: the portion exceeding the expected sales volume is sold at a price reduction of 50% of the sales price in 2023. This study will give the optimal crop planting program for each of the two scenarios.

3.2. Establishing the objective function

3.2.1 Determination of sales

According to the $profit = sales - \cos t$, respectively, to solve for a particular year or season on a plot of a certain crop in the season sales and the corresponding cost, you can find the cost of the crop, and then on the plot, time and crop types can be summed up to get the required time period of the time period of all the crops planted in all the plots of the profit earned.

The above analysis shows that it is necessary to start with a study of a particular crop in a particular plot at a particular time. Normally, $sales = acreage \times mu\ yield \times unit\ price\ of\ goods\ sold$.

Let the sales be C, then:

$$C = x_{ijt} \times a_{ij} \times q_{ij}^{(1)} \tag{1}$$

However, the total production of a certain crop per season exceeds the corresponding expected sales and the excess cannot be sold properly. So a step function is used there to correct C.

A step function, also known as a Heaviside function, is a special type of continuous time function that jumps from one value to another [1, 2].

$$\varepsilon(t)=\begin{cases}0 & t<0\\ 1 & t\geq 0\end{cases} \tag{2}$$

Based on this question, using the step function, construct the following equation:

$$\varepsilon(n)-\alpha\varepsilon(n-r_j^{(1)}) \tag{3}$$

Multiplying this equation with the expression for sales gives the corrected result:

$$x_{ijt}\times a_{ij}\times q_{ij}^{(1)}\times[\varepsilon(n)-\alpha\varepsilon(n-r_j^{(1)})] \tag{4}$$

The equation represents the revised sales of a crop for a given plot at a given time. The portion of the total production of this crop per season that does not exceed the corresponding expected sales volume is sold at the original unit price sold, and the portion that exceeds the corresponding expected sales volume is represented by adjusting the values of α to 1 and 0.5, respectively, based on the pre-established two operations of stagnation of the portion of the sales volume that exceeds the expected sales volume and price reductions of the portion that exceeds the unit price of goods sold at 50 percent of the sales price in the year 2023, respectively. price reduction by 50% of the 2023 sales price.

From the above analysis, it can be concluded that the sales of a particular crop in a plot in a given year in the first type of cropland type are:

$$C_A=x_{ijt}\cdot a_{ij}\cdot[\varepsilon(n)-\alpha\varepsilon(n-r_j^{(1)})]\cdot q_{ij}^{(1)} \tag{5}$$

Sales of a particular crop in a plot in the first quarter of a given year in the second type of cropland are:

$$C_{B1}=y_{ij(2t-1)}\cdot b_{ij}\cdot[\varepsilon(n)-\alpha\varepsilon(n-r_j^{(2)})]\cdot q_{ij}^{(2)} \tag{6}$$

Sales of a particular crop from a plot in the second season of a given year in the second category of cropland types are:

$$C_{B2}=y_{ij(2t)}\cdot {}^{*}b_{ij}\cdot[\varepsilon(n)-\alpha\varepsilon(n-r_j^{(2)})]\cdot {}^{*}q_{ij}^{(2)} \tag{7}$$

Where $q_{ij}^{(1)}, r_j^{(1)}$ denotes the unit price of goods sold with expected sales volume of the j th crop in the first type of cropland in year t in the i th cropland; $y_{ij(2t-1)}, q_{ij}^{(2)}, r_j^{(2)}$ denote the acreage, unit price of goods sold with expected sales volume of the j th crop in the second type of cropland in the i th cropland in the 2t-1 season; and $y_{ij(2t)}, {}^{*}q_{ij}^{(2)}, r_j^{(2)}$ denote the acreage of the j th crop in the second type of cropland in the i th cropland in the 2t season, unit price of goods sold and expected sales volume.

3.2.2 Determination of unit price of goods sold

Since the official data only shows the range of unit prices sold for each crop in different plot types in a year, in order to ensure the randomness of unit prices and to determine specific unit prices, it is necessary to use 3σ formula to determine the unit prices sold for each crop in different plot types in each year for the interval of the unit price range.

The expected sales volume, cost of cultivation, mu yield, and unit price of goods sold for each crop are assumed to remain stable relative to 2023, so that the unit price of goods sold for each crop in each year for the different plot types can be determined by 3σ formula.

3.2.3 Establishment of penalties

The problem of not spreading out too much each season for each crop can be solved by setting up a suitable penalty term for the objective function. Depending on the degree of dispersion of a crop, the penalty term will change accordingly, affecting the results of the objective function [3, 4].

After that, for the problem of how to set up the penalty term, the information entropy will be used as the basis, and the appropriate penalty term will be set up after the transformation.

Information entropy is a basic concept in information theory used to describe the uncertainty of the occurrence of each possible event of an information source. Information entropy refers to the average amount of information in a message after redundancy is eliminated, and can also be understood as the probability of occurrence of a particular message. In information theory, information entropy is used to measure the degree of uncertainty or chaos in a set of data. The more chaotic a system is, the higher the information entropy is; conversely, the more organized the system is, the lower the information entropy is.

The defining equation of information entropy is:

$$H(x)=\sum_{i=1}^{m}[-P(x_i)\ln P(x_i)] \tag{8}$$

Where the maximum value of $H(x)$ in Eq. is $\ln m$.

In this study, the idea of information entropy can be borrowed to create penalty terms, associated with the degree of dispersion of a certain crop.

According to the definition of information entropy the information entropy of the first land type can be obtained as:

$$H(x)=-\frac{\sum_{i=1}^{6}x_{ijt}}{\sum_{i=1}^{26}x_{ijt}}\cdot\ln\frac{\sum_{i=1}^{6}x_{ijt}}{\sum_{i=1}^{26}x_{ijt}}-\frac{\sum_{i=9}^{20}x_{ijt}}{\sum_{i=1}^{26}x_{ijt}}\cdot\ln\frac{\sum_{i=9}^{20}x_{ijt}}{\sum_{i=1}^{26}x_{ijt}}-\frac{\sum_{i=21}^{26}x_{ijt}}{\sum_{i=1}^{26}x_{ijt}}\cdot\ln\frac{\sum_{i=21}^{26}x_{ijt}}{\sum_{i=1}^{26}x_{ijt}} \tag{9}$$

From the definition of information entropy, it can be seen that when a certain crop is planted more centrally, the value of H(x) is smaller, and when a certain crop is planted more dispersed, the value of H(x) is larger. If a planted crop is not planted in all plots in a certain cropland type, the value of information entropy is set to 1, and the corresponding penalty term for this crop is 0 at this time.

From the information entropy formula, the penalty term for the first type of cropland can be obtained after transformation as:

$$F_A=1-\frac{-\frac{\sum_{i=1}^{6}x_{ijt}}{\sum_{i=1}^{26}x_{ijt}}\cdot\ln\frac{\sum_{i=1}^{6}x_{ijt}}{\sum_{i=1}^{26}x_{ijt}}-\frac{\sum_{i=9}^{20}x_{ijt}}{\sum_{i=1}^{26}x_{ijt}}\cdot\ln\frac{\sum_{i=9}^{20}x_{ijt}}{\sum_{i=1}^{26}x_{ijt}}-\frac{\sum_{i=21}^{26}x_{ijt}}{\sum_{i=1}^{26}x_{ijt}}\cdot\ln\frac{\sum_{i=21}^{26}x_{ijt}}{\sum_{i=1}^{26}x_{ijt}}}{\ln 3} \tag{10}$$

The penalty term for the second cropland type is:

$$F_B=1-\frac{-\frac{\sum_{i=1}^{8}y_{ijt}}{\sum_{i=1}^{28}y_{ijt}}\cdot\ln\frac{\sum_{i=1}^{8}y_{ijt}}{\sum_{i=1}^{28}y_{ijt}}-\frac{\sum_{i=9}^{24}y_{ijt}}{\sum_{i=1}^{28}y_{ijt}}\cdot\ln\frac{\sum_{i=9}^{24}y_{ijt}}{\sum_{i=1}^{28}y_{ijt}}-\frac{\sum_{i=25}^{28}y_{ijt}}{\sum_{i=1}^{28}y_{ijt}}\cdot\ln\frac{\sum_{i=25}^{28}y_{ijt}}{\sum_{i=1}^{28}y_{ijt}}}{\ln 3} \tag{11}$$

3.2.4 Determination of the objective function

This study is to investigate the optimal cropping program for crops in the countryside for the years 2024-2030, simply by maximizing the profit from the sale of all crops in all plots and with a penalty term for that seven-year period. Accordingly, it can be seen that the final objective function is a function that solves for the total profit with a penalty term.

Based on the expression for sales and penalty term obtained in the previous section, the total profit with penalty term over seven years can be calculated by dividing all cultivated land into two main categories respectively, and the objective function can be obtained as:

$$\sum_{j=1}^{15}\left\{\sum_{t=1}^{7}\left\{\left\{\sum_{i=1}^{26}C_A\right\}-\sum_{i=1}^{26}x_{ijt}\cdot p_{ij}^{(1)}\right\}\cdot\left\{\left(\sum_{t=1}^{7}F_A\right)\div 7\right\}\right\}+ \\ \sum_{j=1}^{26}\left\{\left\{\sum_{t=1}^{7}\left\{\left\{\sum_{i=1}^{28}C_{B1}\right\}-\sum_{i=1}^{28}y_{ij(2t-1)}\cdot p_{ij}^{(2)}\right\}+\sum_{t=1}^{7}\left\{\left\{\sum_{i=1}^{28}C_{B2}\right\}-\sum_{i=1}^{28}y_{ij(2t)}\cdot {}^{*}p_{ij}^{(2)}\right\}\right\}\cdot\left\{\left(\sum_{t=1}^{14}F_B\right)\div 14\right\}\right\} \tag{12}$$

Where when the total production of a crop per season exceeds the corresponding expected sales volume, α is taken as 1 if the excess is stagnant and 0.5 if the excess is sold at a reduced price of 50% of the sales price in 2023. $p_{ij}^{(1)}$ denotes the cost of cultivation of the j th crop in the first cropland type in the i th cropland in year t; $y_{ij(2t-1)}, p_{ij}^{(2)}$ denotes the area, cost of cultivation of the j th crop in the second cropland type in season $2t-1$ in the i th cropland; $y_{ij(2t)}, {}^{*}p_{ij}^{(2)}$ denotes the area, cost of cultivation of the j th crop in the second cropland type in season $2t$ in the i th cropland.

The equation above is the objective function with respect to total profit.

4. Model constraint analysis

4.1. Planting requirements

Considering the reality that rice can only be grown in wetland and in a single season. Therefore, rice needs to be planted in the first season and at the same time it cannot be planted in the second season. The constraints exist as follows:

$$\begin{cases}\sum_{i=9}^{28}y_{i1t}+\sum_{i=1}^{28}\sum_{j=20}^{26}y_{ijt}=0 \quad (t=1,3,5,\cdots,13)\\ \sum_{i=1}^{28}y_{i1t}+\sum_{i=1}^{24}\sum_{j=2}^{19}y_{ijt}+\sum_{i=9}^{28}\sum_{j=20}^{22}y_{ijt}+\sum_{i=1}^{8}\sum_{j=23}^{26}y_{ijt}+\sum_{i=25}^{28}\sum_{j=23}^{26}y_{ijt}=0 \quad (t=2,4,6,\cdots,14)\\ \left(\sum_{j=20}^{22}y_{ijt}\right)\cdot y_{i1(t-1)}=0 \quad (t=2,4,6,\cdots,14; i=1,2,\cdots,7,8)\end{cases} \tag{13}$$

4.2. Growth pattern

According to the growth pattern of crops, each crop cannot be planted in successive heavy crops on the same type of arable land in order to safeguard the yield of crops. At the same time, it is necessary to plant legume crops at least once in three years on all land in each plot from 2023 onwards, as soil containing legume crop rhizobacteria favors the growth of other crops. Therefore, the following constraints can be made:

$$\begin{cases}x_{ijt}\cdot x_{ij(t-1)}=0 \quad (t=2,3,\cdots,6,7; i=1,2,\cdots,25,26; j=1,2,\cdots,14,15)\\ x_{ij1}\cdot x_{ij}{}'=0 \quad (i=1,2,\cdots,25,26; j=1,2,\cdots,14,15)\end{cases} \\ \begin{cases}y_{i1t}\cdot y_{i1(t-2)}=0 \quad (t=3,5,\cdots,11,13; i=1,2,\cdots,7,8)\\ y_{i11}\cdot y_{i1}{}'^{(2)}=0 \quad (i=25,26,27,28; j=2,3,\cdots,18,19)\end{cases} \\ \begin{cases}y_{ijt}\cdot y_{ij(t-1)}=0 \quad (t=2,3,\cdots,13,14; i=25,26,27,28; j=2,3,\cdots,18,19)\\ y_{ij1}\cdot y_{ij}{}'^{(2)}=0 \quad (i=25,26,27,28; j=2,3,\cdots,18,19)\end{cases} \tag{14}$$

4.3. Easy to farm and manage

The planting scheme should consider the convenience of tillage operations and field management, and needs to satisfy two scenarios: each crop should not be too dispersed in each season, and each crop should not be planted in too small an area in a single Plot area. In this case, the dispersion of each crop is reflected in the penalty term of the objective function. Therefore, only the problem that the area planted with each crop should not be too small is considered below. From this, the following constraints can be made:

$$\begin{cases} x_{ijt} \geq s_{\min,i}^{(1)} \quad (i=1,2,\cdots,25,26;\ j=1,2,\cdots,14,15; t=1,2,\cdots,6,7) \\ y_{ijt} \geq s_{\min,i}^{(1)} \quad (i=1,2,\cdots,7,8;\ j=1,2,\cdots,25,26; t=1,2,\cdots,13,14) \\ y_{ijt} \geq s_{\min}^{(2)} \quad (i=9,10,\cdots,27,28;\ j=1,2,\cdots,25,26; t=1,2,\cdots,13,14) \end{cases} \tag{15}$$

Where $s_{\min,i}^{(1)}$ denotes the minimum area of all cultivated land except greenhouses and intelligent greenhouses and 1/6 of the area of the i th land both, and $s_{\min}^{(2)}$ denotes 1/2 of the area of cultivated land of greenhouses and intelligent greenhouses, i.e., 0.3 acres.

4.4. Actual conditions

Depending on the actual situation of cultivation of arable land, two requirements need to be met. On the one hand, the total number of acres planted with crops needs to be equal to the total area of the cultivated plot. On the other hand, the sales from the sale of all crops in the previous year should be greater than the cost of cultivation in the second year. Therefore, for these two practical conditions, the constraints are determined as follows:

$$\begin{gathered} \begin{cases} \sum_{j=1}^{15} x_{ijt} = s_i^{(1)} \quad (t=1,2,\cdots,6,7; i=1,2,\cdots,25,26) \\ \sum_{j=1}^{26} y_{ijt} = s_i^{(2)} \quad (t=1,2,\cdots,13,14; i=1,2,\cdots,27,28) \end{cases} \\ \sum_{t=1}^{k}\left\{\sum_{j=1}^{15}\left\{\sum_{i=1}^{26} \mathrm{C_A}\right\}\right\} + \sum_{t=1}^{2k}\left\{\sum_{j=1}^{26}\left\{\left\{\sum_{i=1}^{28} \mathrm{C_{B1}}\right\} + \left\{\sum_{i=1}^{28} \mathrm{C_{B2}}\right\}\right\}\right\} + V_{23} \geq \\ \sum_{t=1}^{k+1}\left\{\sum_{j=1}^{15}\left[\left(\sum_{i=1}^{26} x_{ijt}\right)\cdot p_{ij}^{(1)}\right]\right\} + \sum_{t=1}^{2(k+1)}\left\{\sum_{j=1}^{26}\left[\left(\sum_{i=1}^{28} y_{ij(2t-1)}\right)\cdot p_{ij}^{(2)} + \left(\sum_{i=1}^{28} y_{ij(2t)}\right)\cdot {}^{*}p_{ij}^{(2)}\right]\right\} \\ (k=1,2,\cdots,5,6) \end{gathered} \tag{16}$$

5. Application of genetic algorithms in crop planting optimization

In this study, genetic algorithms were used to simulate natural selection by iteratively optimizing solutions in the population through selection, crossover and mutation operations. Monte Carlo method is used to randomly generate initial population samples and select the optimal samples by fitness [5-7]. In this case, the crossover operation of the genetic algorithm generates new samples by randomly dividing and exchanging the parental matrices, while the mutation operation replaces parts of the sample matrices by randomly generating matrices, and ultimately iteratively generates the optimal solution [8-12].

The iterative process of the genetic algorithm to solve this model is shown below:

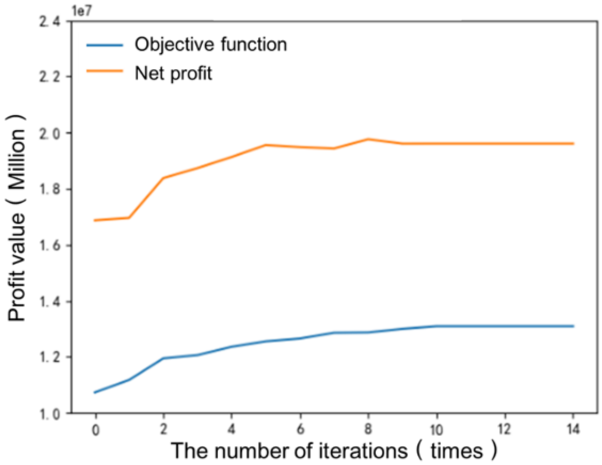

Figure 2. Convergence curves for scenario 1 where all the excess is wasted

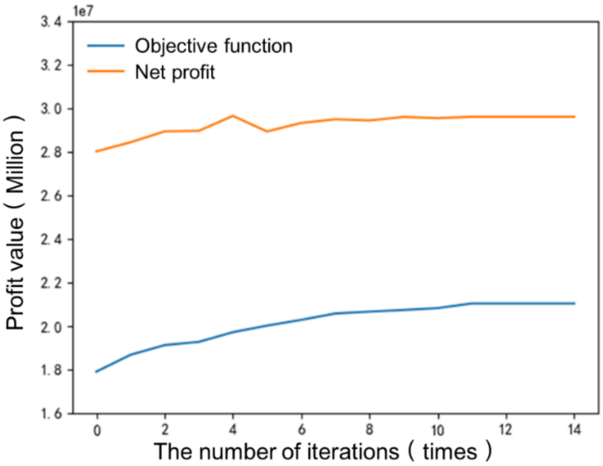

Figure 3. Convergence curves for scenario II with half-price sale in excess

Figures 2 and 3 represent that under the conditions of scenario I and scenario II, respectively, as the number of iterations of the genetic algorithm increases, the net profit of the crop as well as the value of the objective function with the added penalty term gradually converge to a certain value, which is the optimal solution.

By observing the images, it can be seen that both curves are characterized by fast convergence, on the one hand, the Monte Carlo method can find out the better initial samples faster, and on the other hand, the genetic algorithm has a superiority compared with other heuristic algorithms.

From the above figure, it can be seen that the curve in scenario one starts to converge gradually after the eighth generation, and its net profit curve shows a decreasing trend in the fifth and eighth generations, and the curve in scenario two starts to suffer convergence gradually after the tenth generation, and its net profit curve shows a decreasing trend in the fourth generation, which indicates that the penalty term in the objective function of this model has a certain impact on the net profit, and the practical problems of considering the convenience of farming operations and field management are taken into account. Thus, we choose to sacrifice some of the benefits to get the crop planting program with the best comprehensive effect.

By solving the model, the crop cultivation scenarios and their resulting net profits from 2023 to 2030 can be obtained, and some of the results are shown in the figure below. The value of the objective function in scenario one is 13636516.12 Yuan and the net profit for seven years is 19869903.50 Yuan; in scenario two the objective function is 21578983.47 Yuan and the net profit for seven years is 30917647.25 Yuan.

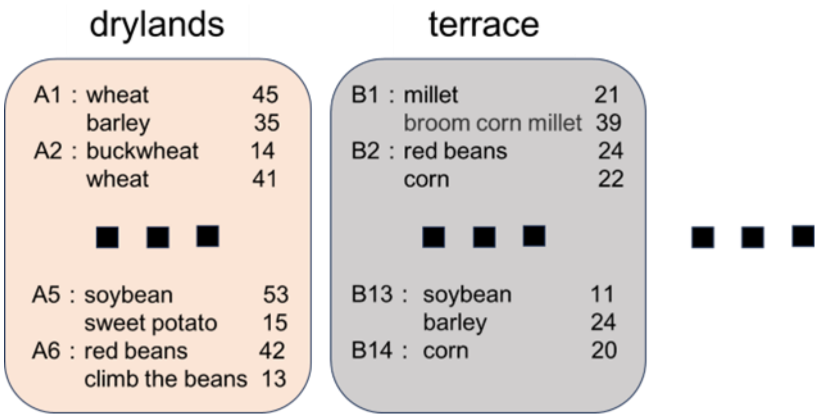

Figure 4. Scenario 1 Selected Planting Scenarios for 2024 (in acres)

Figure 4 represents the types of crops and corresponding acres of cropland that need to be planted for each land type when the stagnant portion is all wasted to maximize total profits.

6. Conclusion

This study gives the optimal cropping scenarios for crops from 2024 to 2030 for the given two scenarios based on the data related to crops in mid-2023. First, the data need to be combined and summarized to obtain the total production of each crop in 2023 as the expected sales volume for the next seven years. At the same time, the unit price of goods sold for each crop is determined using the principle of normal distribution. After that, the optimization model is established with profit maximization as the objective function, crop planting requirements, growth patterns, actual conditions and ease of cultivation and management as the constraints, and the introduction of penalty terms. Finally, the Monte Carlo algorithm was used to determine the original samples and solve the optimal planting scheme of crops from 2024 to 2030 in the countryside under two scenarios by genetic algorithm. It can be seen that for farmers, the program of selling the stagnant portion at half price can help them to get more profit in the same scenario of cultivation. Through this study, it is recommended that the portion of the crop that exceeds the corresponding expected sales volume should be sold at a reduced price as much as possible instead of just selling it at a stalled price in order to get a higher net profit. However, this study also has some shortcomings, for how much price to sell the stagnant portion this study only considered two scenarios of total waste and half price. Later on, the research on this aspect will continue to explore the effect of the specific selling scheme of the slow-selling portion on the total profit.

This paper provides a research idea and framework applied to the field of agricultural economic optimization, through the Monte Carlo method to randomly generate the initial population samples after the use of genetic algorithms to simulate the natural selection, after iterating many times to obtain the optimal solution of convergence, proving the feasibility of crop planting optimization research based on genetic algorithms and Monte Carlo method.

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