Planting Strategy Modelling Based on Linear Regression with Complex Constraints and Stochastic Simulation

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Abstract: With the continuous development of crop-related science and technology, the optimisation of crop planting profits and the maximisation of resource utilisation has become a hot topic of the times. In this paper, based on the detailed data information provided, a mathematical model is established for analysis, so as to formulate reasonable crop cultivation varieties and area plots, and promote the maximisation of profit and resource utilisation. This paper firstly establishes an optimization model with complex constraints based on the total crop production in 2023; takes 5%~7.5% as the interval, simulates the expected sales volume and change data of other crops, and then takes this as the new constraint, combines with the previous optimization model, establishes an optimization model that introduces stochastic simulation; finally, it introduces the substitutability and complementarities of various types of crops, and establishes an optimization model through Spearman's correlation coefficient, so as to maximize profit and resource utilization.

1. Introduction

With the rapid development of China's social economy and the significant improvement of the quality of life of the people, the consumer market has shown unprecedented vitality and steady growth. In this context, crop products, in the continuous development of science and technology, such as the emergence of intelligent greenhouses, its market demand is huge and indispensable. Crop consumption, with its daily high-frequency and quality-seeking characteristics, signals a huge market potential.

However, the crop market also faces many challenges, such as the cyclical nature of crop growth, the specificity of the growing environment, and the fixed nature of the growing time. These challenges make the rationalization of planting schemes for different varieties of crops a key aspect of cost control and profit optimization. In addition, accurately grasping the yields, selling prices, and substitution and complementarity of crops at different times of the year is also an important consideration in meeting market demand and optimising profits. Optimising the cropping structure has become a top priority.

In order to effectively address these challenges and maximise economic and social benefits, we need to rely on rigorous mathematical analysis tools to conduct in-depth research on crop growth habits, yields, selling prices, etc., and develop a set of dynamically adapted, flexible and efficient crop planting strategies. At the same time, based on the results of these analyses, we consider the substitution and complementary relationship between crop varieties, and put forward some of our alternative optimal solutions in special extreme situations, as well as the relationship between sales volume, sales price and mu yield, etc., which is more in line with the actual situation. These are not only in line with our current desire to maximise profits and promote economic growth, but also suggest better ways to rationalise the use of resources[1][2][3].

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2. Model Assumption

Assume that the expected sales volume, planting costs, acreage, and sales prices of various crops in 2024-2030 will remain stable relative to 2023, and that the crops planted in each season will be sold in the current season.

Assume that the expected sales volume of various crops in 2024 to 2030 is the actual total production in 2023.

Assume that a maximum of three crops are grown simultaneously in one shed.

Assume that the number of existing arable land in the countryside is fixed and the area remains unchanged, and that natural factors cannot change the type of arable land and the size of the area.

Assume that there will be no extreme natural disasters (such as floods, droughts, typhoons, earthquakes, etc.) that will lead to a large-scale reduction in crop yields in the countryside from 2024 to 2030.

Assume that there will be no major breakthroughs in crop cultivation technology in the countryside from 2024 to 2030, i.e., the impact of technological advances on crop yields and cultivation costs will not be taken into account.

Assume that there is an adequate supply of basic agricultural materials (e.g. seeds, fertilisers, etc.) in the village, and that there are no shortages.

3. Modelling and Solving

3.1 Linear Regression Modelling

Firstly, data preprocessing was carried out. In this paper, the total yields of different crops were calculated for different plots in different seasons and summed up for flat dry land, terraced land and hillside land, and for watered land, normal greenhouse and smart greenhouse respectively. Some of the results obtained are shown in Table 1 and Table 2.

Table 1. Results of total yield of selected crops in different plots in different seasons

Crop No.	Crop Name	Crop Type	Area	Season	Yield per Acre	Product
Product6	Barley	Cereals	80	Single	800	64000
7	Corn	Cereals	55	Single	1000	55000
7	Corn	Cereals	35	Single	1000	35000
1	Soya Bean	Cereals (Bean)	72	Single	400	28800
4	Mung Bean	Cereals (Bean)	68	Single	350	23800

Table 2. Total production results for different types of plots in 2023

Type of plot	Product
Flat drylands, terraces and hillsides	658255
Watered land, ordinary greenhouses, intelligent greenhouses	600810

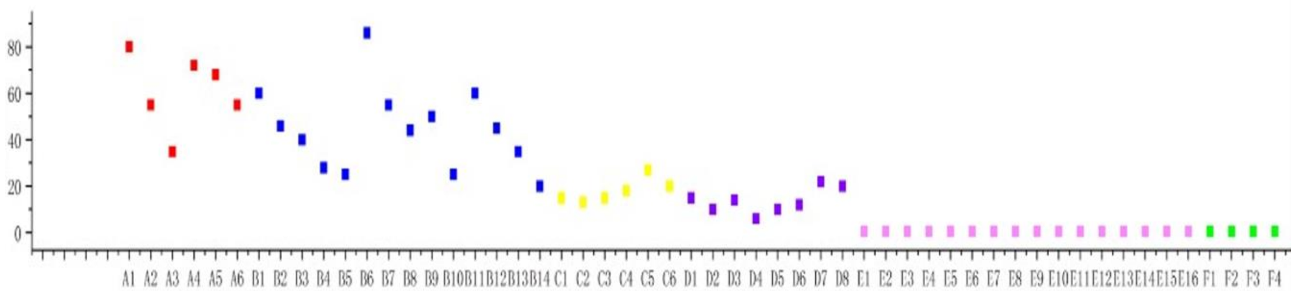

Fig. 1 Scatterplot of land area occupied by different arable lands

Based on the area data of different plots, a scatter plot of area distribution of different plots can be drawn (as shown in Fig. 1). Observing the scatter plot, it can be found that among the flat dry land, terraced land and hillside land, the smallest plot is C2 with an area of 13 acres, and among the watered land, the smallest plot is D4 with an area of 6 acres. Both ordinary and smart greenhouses were 0.6 acres and the minimum area for each crop season was 0.3 acres.

According to the data of crop cultivation in 2023, the three-dimensional scatter plot of mu yield of different single-season food crops in three different plots respectively can be plotted, as shown in Fig. 2, the highest mu yield is pumpkin and sweet potato in hillside land, which is 2,700 and 2,000 pounds respectively, and the lowest mu yield is buckwheat in hillside land and mung bean in terraced land, which is 100 pounds and 330 pounds respectively. The three-dimensional scatter plots of the mu yield of different crops in watered land, ordinary greenhouses and intelligent greenhouses respectively are plotted, as shown in Fig. 3, the highest mu yield is the cucumber in the first season of watered land and the second season of intelligent greenhouses, which is 15,000 and 13,500 pounds, respectively, and the lowest mu yield is the single-season rice in watered land, which is 500 pounds.

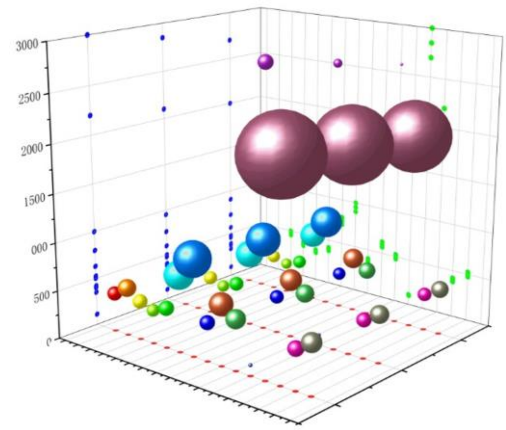

Fig. 2 Distribution of crop yields per acre in dryland, terraced and hillside soils

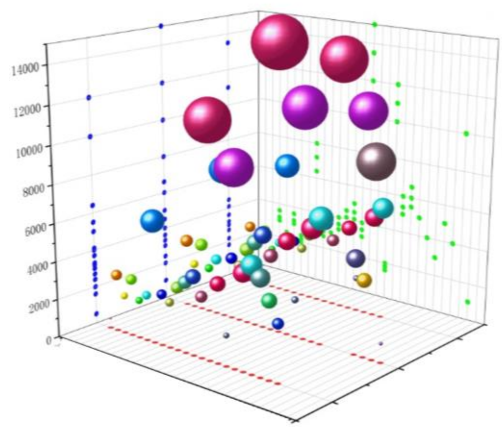

Fig. 3 Three-dimensional scatterplot of acreage yield of watered and greenhouse crops

In order to simplify the complexity of the model, this paper divides crops into two major categories according to soil conditions for modelling and solving respectively, i.e., crops planted in flat and dry land, terraced land and hillside land, as well as crops planted in water-consumed land, ordinary greenhouses and intelligent greenhouses. Then there are two sets as follows:

$$\begin{cases} A_1 = \{\text{Flat drylands, terraces, hillsides}\} \\ A_2 = \{\text{Watered land, greenhouses}\} \end{cases} \tag{1}$$

For flat dry land, terraces and slopes, there are a total of 26 plots of flat dry land, terraces and slopes in the village, with a total of 15 crops planted on each of the three different types of plots, based on the results of crop numbering and plot numbering. The schematic function under 0-1 planning can be set:

$$a_{ij}=\begin{cases}1,\\0,\end{cases} i=1,2,\cdots,26, j=1,2,\cdots,15 \tag{2}$$

When $a_{ij}=1$, it means that the jth crop is selected for cultivation in the i-th plot and vice versa. The existing constraints are transformed into mathematical expressions：

a) Requiring all land in each plot (including sheds) to be planted with legume crops (i.e., crops numbered 1 to 5) at least once in three years, there are：

$$1\le\sum_{j=1}^{5}a_{ij,t}+\sum_{j=1}^{5}a_{ij,t+1}+\sum_{j=1}^{5}a_{ij,t+2}\le 3 \tag{3}$$

b) If each crop cannot be planted in the same plot (including greenhouses) in consecutive crops, i.e. the same crop cannot be planted in the same plot for two consecutive years (two seasons), then there is:

$$\sum_{j=1}^{15}\left|a_{ij,t}-a_{ij,t-1}\right|=2 \tag{4}$$

c) Each crop must not be spread too thinly each season, i.e. each crop must not be planted on only one of the dryland, terraced and hillside areas, if any:

$$\sum_{j=1}^{15}a_{ij}=1 \tag{5}$$

d) The area of each crop planted in a single plot (including greenhouses) should not be too small:

$$\sum_{i=1}^{26}S_i a_{ij}\ge S_{min_1} \tag{6}$$

For the portion of the actual production exceeding the expected production to be treated as stagnant sales, let q_{ij} be the yield per unit area of the jth crop selected for planting in the ith plot, c_{ij} be the unit cost of the jth crop selected for planting in the ith plot, and P_j be the unit price of the jth crop sold, then the total actual production.

Based on the results of data preprocessing, the actual production of soil dryland, terraces and slopes in 2023 is taken as the expected future sales volume, which can be set as the actual sales volume

$$R_j=\begin{cases}\sum_{i=1}^{26}\sum_{j=1}^{15}Q_{ij}, & \sum_{i=1}^{26}\sum_{j=1}^{15}Q_{ij}\le 658255\\ 658255, & \sum_{i=1}^{26}\sum_{j=1}^{15}Q_{ij} > 658255\end{cases} \tag{7}$$

Objective function for that case:

$$f_{1max}=\sum_{j=1}^{15}\left[P_jR_j-\sum_{i=1}^{26}Q_{ij}\,c_{ij}\right] \tag{8}$$

For the excess, sell at a 50 per cent price reduction, and then set up the schematic function under 0-1 planning:

$$u_j=\begin{cases}1, R_j>658255\\0, R_j\le 658255\end{cases} j=1,2,\cdots,15 \tag{9}$$

Then the objective function in that case:

$$f_{2max} = \sum_{j=1}^{15} \left\{ \left[P_j R_j + u_j P_j \left(R_j - 658255 \right) \times 50\% \right] - \sum_{i=1}^{26} Q_{ij} c_{ij} \right\} \tag{10}$$

For watered plots and sheds, according to the results of crop numbering and plot numbering, there are 28 watered plots and sheds in the countryside, with a total of 26 crops grown on each of the three different types of plots (sheds). The schematic function under 0-1 planning can be set:

$$a_{ij,m} = \begin{cases} 1, \\ 0, \end{cases} i = 27,28,\cdots,54, j = 16,17,\cdots,41 \tag{11}$$

When $a_{ij,m} = 1$, it means that the jth crop is selected for the mth season in the i-th plot. The constraints are the same as above and the expression is changed to:

$$1 \le \sum_{j=17}^{19} a_{ij,m} + \sum_{j=17}^{19} a_{ij,m+1} + \sum_{j=17}^{19} a_{ij,m+2} \le 3 \tag{12}$$

$$\sum_{j=16}^{41} \left| a_{ij,m} - a_{ij,m-1} \right| = 2 \tag{13}$$

$$\sum_{j=16}^{41} a_{ij,m} = 1 \tag{14}$$

Additional constraint: the area of each crop grown on a single plot (including greenhouses) should not be too small:

$$\sum_{i=27}^{34} S_i a_{ij,m} \ge S_{min_2}, j = 16,17,\cdots,34 \tag{15}$$

$$\sum_{i=35}^{54} S_i a_{ij,m} \ge S_{min_3}, j = 17,18,\cdots,41 \tag{16}$$

where $S_{min_2} = 6$, $S_{min_3} = 0.2$

Only one season of rice or two seasons of vegetables can be grown on irrigated land, and only cabbage, white radish and red radish can be grown in the second season:

$$\begin{cases} \sum_{j=17}^{34} a_{i,j,1} + a_{i,16,1} = 1 \\ \sum_{j=35}^{37} a_{i,j,2} \le 1 \end{cases}, i = 27,28,\cdots,34 \tag{17}$$

Ordinary greenhouses must grow one season of vegetables and one season of edible mushrooms:

$$\begin{cases} \sum_{j=17}^{34} a_{i,j,1} = 1 \\ \sum_{j=38}^{41} a_{i,j,2} = 1 \end{cases}, i = 35,36,\cdots,50 \tag{18}$$

Smart greenhouses must grow two seasons of vegetables:

$$\begin{cases} \sum_{j=17}^{37} a_{i,j,1} = 1 \\ \qquad\qquad\qquad i = 51,52,53,54 \\ \sum_{j=17}^{37} a_{i,j,2} = 1 \end{cases} \tag{19}$$

The objective function is the same as above, and is considered in two ways, case 1: the portion of the actual production exceeding the expected production is treated as lag; case 2: the portion exceeding the expected production is sold at a reduced price of 50 per cent, and the objective function expressions are, respectively, as follows:

$$f_{3max} = \sum_{j=16}^{41} \sum_{m=1}^{2} \left[P_{j,m} R_{j,m} - \sum_{i=27}^{54} Q_{i,j,m} c_{i,j,m} \right] \tag{20}$$

$$f_{2max} = \sum_{j=16}^{41} \sum_{m=1}^{2} \left\{ \left[P_{j,m} R_{j,m} + v_{j,m} P_{j,m} \left(R_{j,m} - 6 \right) \times 50\% \right] - \sum_{i=1}^{26} Q_{ij} c_{ij} \right\} \tag{21}$$

In this paper, python language is used for programming to solve the optimisation model to get the optimal planting scheme of crops using the constraints of planting legume crops, and some of the planting schemes for the year 2024 are shown in Table 3:

Table 3. Optimal cropping programmes for crops under ideal conditions (partial)

Name of the Plot	soya bean	black bean	azuki bean	……	mushroom
A1	0	0	0	……	0
A2	55	0	0	……	0
A3	0	0	35	……	0
A4	0	0	0	……	0
A5	0	0	0	……	0
A6	0	0	0	……	0
B1	0	0	0	……	0
B2	0	0	0	……	0
B3	0	0	0	……	0
B4	28	0	0	……	0
B5	0	25	0	……	0
B6	0	0	0	……	0

3.2 Considering Stochastic Simulations

By looking up the data, the predicted year-on-year growth data of wheat and corn from 2023 to 2030 fluctuate up and down at 0.22% and 1.8%, respectively, while taking into account the topic of the average annual growth rate of the two in the range of 5% to 10%, so the use of Excel's rand function to generate a random number of 0 to 1 to 5-7.5 as the value of the interval, and take a random number of 5 to 7.5 to represent the average annual growth rate (retain two decimal places). At the same time, the data preprocessing of the annex can be calculated as the total output of wheat and corn is 170,840 pounds and 132,750 pounds, respectively, which can be listed in Table 4.

Table 4. Total production of wheat and maize after generating stochastic average growth rates

	2023	2024	2025	2026	2027	2028	2029	2030
Growth Rate		6.23	6.37	6.83	6.47	7.28	7.30	6.65
Wheat Production	170840	181481	193033	206219	219552	235536	252740	269545
Crop Production	132750	141018	14995	160241	170601	183021	196390	209448

Similarly, for other crops, fluctuations in expected sales, changes in acreage, and changes in planting costs are predicted by generating random numbers to produce simulation data. This data is reused in the model above, and after modifying some of the model parameters, the optimisation model based on stochastic simulation is obtained, and its overall expression is shown below:

$$f_{5max,t} = \sum_{j=1}^{41}(R_{j,t}\,P_{j,t} - \sum_{i=1}^{54} Q_{ij,t}c_{ij,t})$$

$$s.t.\begin{cases} \begin{cases} 1 \le \sum_{j=1}^{5} a_{ij,t} + \sum_{j=1}^{5} a_{ij,t+1} + \sum_{j=1}^{5} a_{ij,t+2} \le 3 \\ 1 \le \sum_{j=17}^{19} a_{ij,t} + \sum_{j=17}^{19} a_{ij,t+1} + \sum_{j=17}^{19} a_{ij,t+2} \le 3 \end{cases} \\ \sum_{j=1}^{41} \left| a_{ij,t} - a_{ij,t-1} \right| = 2 \\ \sum_{j=1}^{41} a_{ij} = 1 \\ \begin{cases} \sum_{i=1}^{26} S_i a_{ij,t} \ge S_{min_1} = 13, j = 1,2,\cdots,15 \\ \sum_{i=27}^{34} S_i a_{ij,t} \ge S_{min_2} = 6, j = 16,17,\cdots,34 \\ \sum_{i=35}^{54} S_i a_{ij,t} \ge S_{min_3} = 0.3, j = 17,18,\cdots,41 \end{cases} \\ Q_{ij,t} = a_{ij,t} S_i q_{ij,t} \alpha_{ij,t} \\ R_{j,t} = \sum_{i=1}^{54} Q_{ij,t} \\ \begin{cases} R_{j,t} = R_{j,t-1}\alpha'_{ij,t}, j = 6,7 \\ R_{j,t} = R_{j,t-1}\beta_{i,j,t}, j = 1,2,\cdots,5,8,9,\cdots,41 \end{cases} \\ \begin{cases} P_{j,t} = P_{j,1}, j = 1,2,\cdots,16 \\ P_{j,t} = P_{j,1}(1+5\%)^t, j = 17,18,\cdots,36 \\ P_{j,t} = P_{j,1}(1-2.5\%)^t, j = 37,38,39 \\ P_{j,t} = P_{j,1}(1-5\%)^t, j = 40 \end{cases} \\ c_{ij,t} = c_{ij,1}(1+5\%)^t, j = 1,2,\cdots,41 \end{cases} \quad (22)$$

The model was solved and some of the results are shown in Table 5:

Table 5. Optimal crop cultivation programmes under stochastic simulation (partial)

Name of the Plot	soya bean	black bean	azuki bean	······	mushroom
A1	0	80	0	······	0
A2	0	0	0	······	0
A3	0	0	0	······	0
A4	0	0	0	······	0
A5	0	0	0	······	0
A6	0	0	0	······	0
B1	0	0	0	······	0
B2	0	0	0	······	0
B3	0	0	0	······	0
B4	0	28	0	······	0
B5	0	25	0	······	0
B6	0	0	0	······	0

3.3 Consideration of substitutability and complementarity between crops

Crops are greatly affected by soil resources, water resources, light resources, fertilisers, etc., and have a certain growth cycle, and can be replaced when, and only when, there is little difference in the factors affecting the two different crops that belong to the same broad category, and when the growth cycle is basically the same. However, if the food crops suffered natural disasters and other major losses, often planted vegetable crops as a substitute, because vegetable crops have a relatively short growth cycle, can meet the people's needs in a relatively short period of time. However, based on the assumptions, the existence of this situation is ignored in this paper.

At the same time, due to the nitrogen fixing effect of legumes, it can provide nitrogen for the growth of other crops planted afterwards after it is planted, so legumes can be planted as a complementary crop to other crops.

In general, the methods of correlation include Pearson, Spearman, and kendall algorithms, as well as chi-square and Fisher's tests, etc. Pearson's correlation coefficient is generally used to judge the correlation of consecutive data and requires that the variables satisfy the normal distribution and that there is a linear relationship between the variables. Spearman's correlation coefficient, compared with Pearson's correlation coefficient, does not require the type of data, as long as there are data corresponding to each variable, the correlation of the variables can be handled. The kendall correlation coefficient is generally used to determine the strength of the relationship between ordered variables. The chi-square test can analyse the correlation between unordered variables, but it cannot show the strength of the correlation. Fisher's test is often used to analyse the correlation between dichotomous variables[4][5].

Firstly, we analyse the relationship between expected sales volume and unit sales price, and use SPSSPRO tool to carry out Spearman correlation analysis, and get the correlation coefficient table as Table 6 and the correlation coefficient heat map as shown in Fig. 4.

Table 6. Table of Spearman's correlation coefficients between acre yield and unit sales price

	Acre Yield	Unit Sales Price
Acre Yield	1(0.000***)	-0.16(0.100)
Unit Sales Price	-0.16(0.100)	1(0.000***)

Note: ***, **, * represent 1 per cent, 5 per cent and 10 per cent significance levels, respectively.

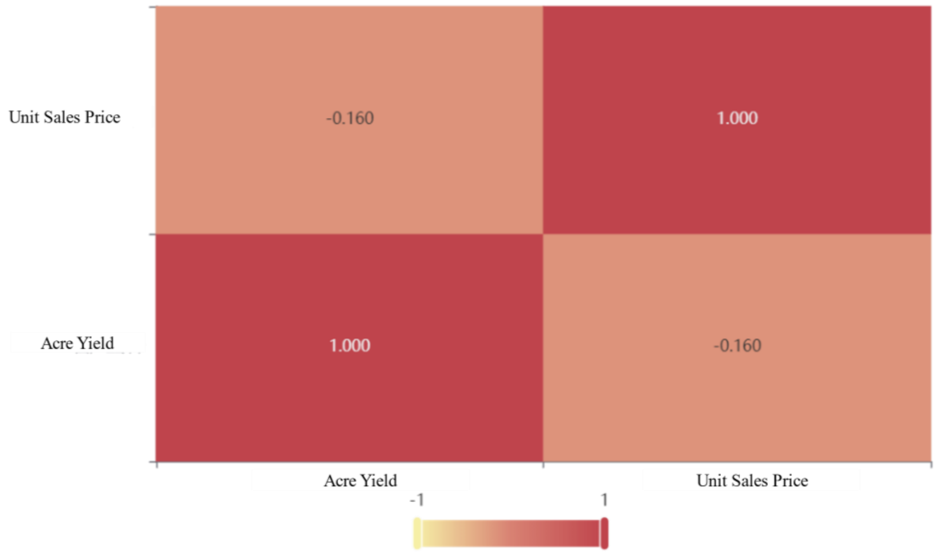

Fig. 4 Heat map of correlation between acre yield and unit sales price

The results showed that the significance P-value was located at the 1% significance level, which is less than 0.05, i.e., presenting significance, and the correlation coefficient between mu yield and unit price of sales r=-0.16, i.e., the two variables were basically not correlated with each other.

For expected sales volume and planting cost, the analysis was done in the same way as above, and the results showed that the significance p-value was located at 1% significance level, less than 0.05, i.e., presenting significance, and the correlation coefficient between mu yield and planting cost r=0.834, i.e., a highly positive correlation between the two variables.

In establishing a more precise correlation, we used a linear regression model to make a judgement, and the linear regression analysis was carried out using the SPSSPRO tool, and the expected linear regression function of sales volume and unit price of sales was:

$$y = 3150.248 - 19.435\xi_1 \quad (23)$$

where ξ_1 denotes the corrected unit sales price (yuan / pound).

Similarly, the linear regression function of expected sales volume and planting cost is:

$$y = 1031.182 + 1.162\xi_2 \quad (24)$$

Where ξ_2 indicates cost of cultivation (yuan / acre)

Based on the above relationship, design the algorithm. Prioritise crops with high profit per acre over pulses in 2024; calculate yields for each crop as close as possible to the projected sales for that year to avoid stagnant sales; plant pulses in order of profit per acre from highest to lowest on plots that have not been planted in two years, based on substitutability; plant wheat and maize on flat dry land, terraces, and slopes on plots that have been planted in two years; plant other crops in order of profit per acre from highest to lowest on plots that have been planted in two years; and plant other crops in order of profit per acre on barns that have been planted in two years, based on substitutability. On the plots that have been planted with beans in two years, plant other crops in the order of profit per mu from high to low; calculate the yield of each crop so that it is as close as possible to the projected sales volume of that year to avoid stagnant sales; on the greenhouses that have been planted with beans in two years, plant edible mushrooms in the order of profit per mu from high to low; calculate the yield of edible mushrooms so that it is as close as possible to the projected sales volume of that year to avoid stagnant sales; and repeat the above operations and carry out the cycle until 2030.

According to the above algorithm, the optimal planting strategy based on stochastic simulation considering crop correlation was obtained and some of the data are shown in Table 7.

Table 7. Optimal planting strategies considering crop correlation (partial)

No.	Plot	Area	2023	2024	2025	2026	2027	2028
1	A1	80	barley	soya bean	barley	barley	soya bean	barley
2	A2	55	corn	barley	soya bean	corn	barley	soya bean
3	A3	35	corn	barley	soya bean	corn	barley	soya bean
4	A4	72	soya bean	buckwheat	corn	soya bean	buckwheat	corn
5	A5	68	green bean	corn	buckwheat	green bean	corn	buckwheat
6	A6	55	millet	green bean	millet	millet	green bean	millet
7	B1	60	barley	corn	soya bean	barley	corn	soya bean
8	B2	46	black bean	millet	corn	black bean	millet	corn
9	B3	40	red bean	barley	millet	red bean	barley	millet

4. Summary

The advantages of this paper's work and modelling are: clever data pre-processing: as no data on the expected future sales volume is given, this paper pre-processes the data so that the crop yield in 2023 is the expected future sales volume of crops in the village; simplified modelling: when designing the optimal planting strategy for the years 2024~2030, the crops are divided into two major groups, and optimisation models are built to solve the problem, which greatly reduces the difficulty and model complexity compared with only building optimisation models for all crops. model, compared with only establishing the optimal model for all crops, it greatly reduces the difficulty and complexity of the model, and facilitates the results; multiple constraints: when designing the optimal planting strategy for 2024~2030, according to the requirements in the total problem and the respective problems, the established optimisation model needs to satisfy multiple complex constraints, which makes the results obtained by the model solution closer to the optimal; the use of information search engine. Closer to the optimal; the use of information search engine: this paper, according to the data related to morel mushrooms in the data, through the search for relevant information, basically determine the more accurate geographic location of the mountainous areas of North China, the use of the Internet has been disclosed on the public information in the preparation of the model narrowed down the scope of the preparation of the data; the use of the random number method: this paper in the simulation of the data, the use of the rand function of Excel software, the operation is more concise, and at the same time, the operation is more concise. In this paper, the rand function of Excel software is used to simulate the data, which makes the operation more concise, and at the same time, the data obtained by simulation is applied to the model solution, which greatly reduces the difficulty of the model solution; Combination of Spearman correlation coefficient method and linear regression model: when judging the relationship between the expected sales volume and the unit price of sales, and the expected sales volume and the cost of planting, the first step is to use Spearman correlation coefficient method to make a judgement, and then use the linear regression model to obtain a regression equation. regression equation. The two methods validate each other to make the correlation results between variables more reasonable.

This paper still needs to be optimised and improved in the following aspects: too many assumptions: the model does not take into account the impact of extreme weather, major technological advances and social factors on crop cultivation in the countryside, which makes the model assumptions too many, and the model design is too ideal and lacks the reasonableness and achievability in practical application Neglecting the complexity of the crop market: this paper does not consider the complex market operation mechanism and competitive relationships at a deeper level, which makes the fluctuations of various indicators not possible. This paper does not consider the complex market operation mechanism and competitive relationship at a deeper level, which makes the fluctuation of various indicators not completely follow the assumption conditions, resulting in the final strategy cannot be close to the optimal.

Finally, the model of this paper can be considered from the following points to promote and improve: expanding the types of crops: although the annex only requires the optimal planting strategy for grain, vegetables and edible fungus crops, the optimisation model of this paper can also be extended to the cultivation of fruits or cotton and other cash crops; expanding the planting area: the problem requires the optimal planting strategy for a rural village in the mountainous area of North China. design, the model can also be extended to planting crops in areas where plains and plateaus are the main terrain; multiple objectives: in addition to profit maximisation as the objective, the model can be extended into a multi-objective optimisation model to improve the overall resource utilisation and make the planting strategy more optimal.

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