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Research on Optimal Allocation of Agricultural Machinery in Nongjiang Farm

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Abstract

Agricultural mechanization has accelerated the modernization of agriculture to a large extent, and agricultural machinery is an important part of agricultural production management. This paper mainly studies the Nongjiang farm in Heilongjiang reclamation area. By searching a large number of data, an integer linear programming model with the lowest cost as the goal is established for the Nongjiang farm, and the optimal number of machines equipped and the required cost are calculated by the Gauss Seidel iteration method programmed by Matlab. Comparing the optimization results with the current situation of agricultural machinery allocation, it is concluded that the optimization results have reduced the number of agricultural machinery by 1186 in total, reduced the average cost per hectare by 614.92 yuan, and saved the total operating cost by 21.3314 million yuan. From the results, it can be seen that the reasonable optimization of agricultural machinery can greatly improve the efficiency of operation and reduce the cost of production, so that more funds will be invested in other areas.

Keywords

Integer linear programming; Matlab; Gauss Seidel iterative method; optimal allocation.

1. INTRODUCTION

Agricultural machinery distribution is an important link in agricultural production. The improper allocation of agricultural machinery leads to the failure of farmland operation to be completed in the best time, thus resulting in a significant decrease in crop yield. Research on optimal allocation of agricultural machinery can achieve the goal of maximum economic benefit with minimum input.

In 1988, D.E.Line of Texas A&M In the United States first proposed a system related to agricultural machinery distribution, which used integer linear programming method to select and distribute the instruments needed for agricultural production. In 1992, H.L.AL et al. developed a system related to decision support for farm machinery management, whose main function is to provide a reasonable reference for resource allocation [1-4]. In 2004, Henning T Sogaad developed the GAMS agricultural machinery system distribution management model by adopting the nonlinear programming model and programming language, and inputting the regional scope, farming mode and field area through the computer input window [5-7]. Finally, the number of power machines to be distributed for farming was output after calculation with the computer programming language [8]. In 2004, E.A.C. Amarena et al., Institute of Agricultural Sciences, University of Guanajuato, Mexico, proposed relevant calculations based on the mixed integer linear programming model for the selection and optimal configuration of agricultural machinery system, and obtained the mixed integer solution. In 2015, S. Ountas came to the power machine operation and management institutions in Denmark, Greece and other places, conducted a long interview with operators in this region, obtained some management methods

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and use process of machine allocation, and obtained the number of machines needed for farm management and future development. In 2017, CarioFilippi established an integer programming model with a certain scale and limited machines to solve the optimal combination of crops with the objective function of maximum cost difference and maximum income. In 2018, Sajad Sabzi used heuristic algorithm to optimize the neural network and find the optimal configuration of potato sprayers to achieve precision agriculture [9-12].

In 1990, Han Kuanjin et al. adopted the sequential programming approximation algorithm when solving nonlinear programming problems, that is, the approximate solution was obtained first, and then the approximation was repeated until the optimal solution was obtained. On the basis of comprehensive analysis of the first several models, Han Kuanjin put forward a mixed integer programming model for agricultural machinery equipment that meets the flow-line operation and the method of two harvests a year. In 2001, Mr. Hu Wenbin made an appropriate improvement on the previous workload method, and based on the characteristics of agricultural production process, established the model of utilization rate of various agricultural machines. In 2001, Wang Jinwu optimized the allocation of rice in Sanjiang Plain and took the timely loss as a decision variable to obtain a nonlinear programming model and optimize it. In 2011, Mr. Zhao Yunsheng adopted the workload method to analyze the distribution of tractors used in agricultural production and calculated the number of tractors needed in agricultural production. In 2014, Yang Fenfen developed three models: linear programming model, operation quantity model and energy method model to optimize agricultural machinery configuration [13-15]. In 2015, Hu Bo analyzed the distribution of agricultural machinery among relevant cooperatives of agricultural institutions and put forward some Suggestions on management and operation. In 2016, According to the actual situation in this region, Li Kai selected the appropriate operation method and carried out the distribution and management of the machinery used in agricultural production. In 2018, Ma Li and Li Shulong analyzed the current situation of comprehensive utilization of rice seedling greenhouse and made reasonable improvement.

2. ESTABLISH AN OPTIMAL OBJECTIVE FUNCTION FOR FARM MACHINERY

In this paper, the annual operation of The Farm is taken as the deadline, and the number of working machines, power machines and supporting machines is selected as the index, and the following variable indexes are set:

Each of the above variables must be an integer.

A function is of the target established to minimize the total annual operating cost of the Nongjiang Farm, which can be divided into three parts, namely, fixed cost of power machinery, fixed cost of operating machinery and variable cost of unit operation. The objective function is shown below:

$$F_{min} = C_i + C_j + C_v \tag{1}$$

(1) Calculation of annual fixed cost of power machinery

The farm's average annual fixed cost of power machines includes the sum of depreciation, interest on capital possession and management fees. The management fee of each power machine is G_i, and the depreciation fee and capital possession interest is F_i.

As for the management fee G_i, each enterprise can only charge according to its own management system, which is usually 10% of the original value of the machine.

$$G_i = \propto P_i \tag{2}$$

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202009_6(9).0008

Table 1. Index of farm machinery allocation impact system

Variable indicators	Variable symbol
Stage K of agricultural production	X_k
Number of Type I power machines to be arranged (a)	X_i
Number of J machines to be arranged(a)	X_j
Number of machines composed of the ith type of power machine and the JTH type of operation machine in the K stage of agricultural production(a)	X_{kij}
The total cost of fixing the engine(yuan)	C_i
Fixed the total cost of the machine(yuan)	C_j
The total cost of the unit can be changed(yuan)	C_v
Annual overheads for type I machines(yuan)	G_i
As a percentage of the original price of the type I machine	$\propto$
The cost of fixing the type I engine, including depreciation and capital possession benefits(yuan)	F_i
Original value of type I power machine(yuan)	P_i
Residual value of type I engine(yuan)The highest temperature	S_i
The number of years of service of the type I power machine after aging(year)	L_i
The interest rate	I
The cost of fixing the JTH type of machine, which includes depreciation and capital possession benefits(yuan)	F_j
The original value of the JTH operating machine(yuan)	P_j
Residual value of type J machine(yuan)	S_j
The number of years of service of the JTH type of machine after aging(year)	L_j
Number of JTH type engines required(a)	X_j
Number of type I self-propelled machines required for stage K of agricultural production(a)	X_{ki00}
Number of days of continuous work in phase K of agricultural production(day)	R_k
The daily variable costs required for a production machine set consisting of type I power machines and Type J operating machines(yuan)	v_{ij}
The daily cost of a self-propelled machine can be changed(yuan)	v_i

Machine depreciation cost and capital possession interest cost are shown below:

$$F_i = P_i \frac{I(1+I)^{Li}}{(1+I)^{Li}-1} - Si \frac{I}{(1+I)^{Li}-1} \tag{3}$$

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202009_6(9).0008

The depreciation life and depreciation rate of large and medium-sized agricultural machinery in Nongjiang farm are shown in the table 2:

Table 2. Depreciation life and rate of large and medium agricultural machinery

The serial number	The name of the agricultural machinery	Depreciation fixed number of year (year)	Allowance for depreciation (%)
1	Large and medium-sized tractors and supporting farm tools	10-15	7-10
2	20-100 horsepower wheeled tractor and supporting farm tools	8-10	10-12
3	More than 100 horsepower wheeled tractor and supporting farm tools	12-14	7-8
4	Combine harvester	12-14	7-8

The fixed cost of power machine is as follows:

$$C_i = (F_i + G_i)X_i \tag{4}$$

(2) Calculation of annual operating machinery fixed cost

The management fee of each operating machine is G_j, and the depreciation fee and capital possession interest are F_j, be:

$$G_j = \propto P_j \tag{5}$$

$$F_j = P_j \frac{I(1+I)^{Lj}}{(1+I)^{Lj}-1} - S_j \frac{I}{(1+I)^{Lj}-1} \tag{6}$$

Operating machine fixed costs are as follows:

$$c_j = (F_j + G_j)X_j \tag{7}$$

Through algebraic solution of the above formula, the result table of annual fixed cost of agricultural machinery in The Nongjiang Farm is obtained, as shown in the following table:

(3) Variable operating costs of agricultural machinery units as follows:

$$C_v = \sum_{k=1}^{K}\sum_{i=1}^{I}\sum_{j=1}^{J} X_{kij}R_k v_{ij} + \sum_{k=1}^{K}\sum_{i=1}^{I} X_{ki0}R_k v_i \tag{8}$$

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202009_6(9).0008

Table 3. Calculation results of annual fixed cost of agricultural machinery in Nongjiang farm

The name of the agricultural machinery	Price (Ten thousand yuan)	number	Annual fixed expense (Ten thousand yuan/year)
Dongfanghong tractor	13.6	469	1.96
Kubotian M954K tractor	16.4	83	2.36
Kubotian 1204 wheeled tractor	15.8	111	2.27
Regular CF809 harvester	32	142	4.66
The Waud harvester	14	429	1.97
Foreign horse transplanter	14.1	376	2.06
Jiubaotian rice transplanter	14	280	2.11
Kaixuanwang puddling machine	1.5	186	0.21
Fukuda puddling machine	1.3	267	0.19
6-27 Paddy field plough	1	269	0.15
3+1 Paddy field plough	2	90	0.32
5-27 Paddy field plough	1.3	463	0.19
Wode's rake	2.6	120	0.38
Crass baling machine	15.8	392	2.39
The wham! Baler	14.3	471	2.13
Dill's rake	26.2	358	3.94
Fukuda rake	5.8	59	0.87

Plug the relevant data into the formula (2-8), after calculation, the result table of variable cost of agricultural machinery in Nongjiang farm is obtained, as shown in the following table:

By solving the above three factors, the objective function of the annual minimum operating cost of The Farm is obtained, as shown below:

$$\begin{aligned} F_{min} &= C_i + C_j + C_v = \sum_{i=1}^{I}(F_i + G_i)X_j + \sum_{j=1}^{J}(F_j + G_j)X_j \\ &+ \sum_{k=1}^{K}\sum_{i=1}^{I}\sum_{j=1}^{J} X_{kij}R_k v_{ij} + \sum_{k=1}^{K}\sum_{i=1}^{I} X_{ki0}R_k v_i \end{aligned} \tag{9}$$

Substitute the value of the above variables into the above equation and get the corresponding result of the objective function. In this paper, 11 decision variables that mainly affect the total cost of agricultural production are selected and 28 types of farm machines and power machines are selected, so there are 308 solving results corresponding to the objective function.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202009_6(9).0008

Table 4. The result of variable cost of agricultural machinery in Nongjiang farm

serial number	The unit operation	Fuel (yuan/ mu)	fix (yuan/ mu)	Salary (yuan/ mu)	total (yuan/hm2)
1	Dongfanghong 904 slurry mixing unit	8	4	2.9	223
2	Futian 1004 puddling unit	9	4	3.5	234.5
3	Foreign horse transplanting plant	5	4	60	1036
4	Kubotian seedling transplanting unit	5	4	60	1036
5	Wode harvesting unit	8	4	11	332
6	CF809 harvesting unit	12	4	10.5	397
7	Foton 1004 Rake group	2	4	1	105
8	Dongfanghong 904 rake group	2	4	1.5	106
9	Dill 1204 rake team	2	4	1	105
10	Dill bundling unit	4	4	2	150
11	Fukuda bundling unit	4	4	2	150
12	Deere dump crew	10	4	4	263.5
13	Dongfang Hongtiandi unit	11	4	3.5	284
14	Foton 1004 repeater unit	10	4	4	263.5

3. ESTABLISHMENT AND SOLUTION OF AGRICULTURAL MACHINERY OPTIMIZATION MODEL

3.1. An Introduction to Integer Programming Models

Integer programming, as the name implies, refers to the integer limit of its variables. In linear models, such as programming the decision variables in a problem $X_i = (i = 1, 2, \ldots, n)$, if the limit is an integer, the model is called an integer linear programming model.

Mathematical expression:

$$\min z = \sum_{j=1}^{n} c_j x_j$$

$$\text{s.t.} \begin{cases} \sum_{j=1}^{n} a_{ij} x_j = (\le , \ge) b_i, \ i = 1, 2, \cdots, m. \\ x_j \in N, \ j = 1, 2, \cdots, n. \end{cases} \tag{10}$$

which, $c_j (j = 1, 2, L, n.)$, $b_i, (i = 1, 2, \cdots, m)$,

$a_{ij} (i = 1, 2, \cdots, m; j = 1, 2, \cdots, m)$ are known,

$x_j (j = 1, 2, \cdots, n.)$ are the decision variables.

3.2. Constraint Equation of Agricultural Machinery Configuration

The optimal objective function has been obtained after sorting out the calculation. Next, the following four constraint inequalities are established by referring to the research contents of a large number of experts and researchers and according to the actual situation.

(1)Inequalities are established for operating quantities

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202009_6(9).0008

In any given task, the total amount of unit work distributed at each farming stage is greater than or equal to the amount of work to be completed by the task. Suppose that the NTH project worked continuously for R_k days in the farming stage from K_m to K_n, the number of units was X_kij, the working efficiency of units was A_kij, and the total workload was S, then the following constraints should be satisfied:

$$\sum_{k=Km}^{Kn} R_k \sum_{i=1}^{I} \sum_{j=1}^{J} A_{kij} X_{kij} \geq S \tag{11}$$

(2) The inequality of the number of power machines is established

In each farming period, the number of machines of the same kind allocated must be less than or equal to the number of machines, the power machines as a decision variable, it should meet:

$$\sum_{k=1}^{K} \sum_{j=1}^{J} X_{kij} \geq X_i \tag{12}$$

(3) An inequality is established for the number of operating machines

In each farming period, the number of machines configured with the same kind of machinery must be less than or equal to the allocated number of the machinery, the machine as a decision variable, it should be satisfied.

$$\sum_{k=1}^{K} \sum_{i=1}^{I} X_{kij} \leq X_j \tag{13}$$

(4) Nonnegative constraints on variables

The number of units assigned to any power machine, operation machine and operation unit shall not be negative or decimal, and shall be limited to: $X_i \geq 0$, $X_j \geq 0$, $X_{kij} \geq 0$, each of them takes an integer.

To sum up, an integer linear inequality set for optimal allocation of farm machinery in Nongjiang is obtained, as shown below:

$$F_{min} = \sum_{i=1}^{I} (F_i + G_i) X_j + \sum_{j=1}^{J} (F_j + G_j) X_j + \sum_{k=1}^{K} \sum_{i=1}^{I} \sum_{j=1}^{J} X_{kij} R_k v_{ij} + \sum_{k=1}^{K} \sum_{i=1}^{I} X_{ki0} R_k v_i \tag{14}$$

$$\begin{cases} \sum_{k=Km}^{Kn} R_k \sum_{i=1}^{I} \sum_{j=1}^{J} A_{kij} X_{kij} \geq S \\ \sum_{k=1}^{K} \sum_{j=1}^{J} X_{kij} \leq X_i \\ \sum_{k=1}^{K} \sum_{i=1}^{I} X_{kij} \leq X_j \\ X_i \geq 0, X_j \geq 0, X_{kij} \geq 0 \end{cases} \tag{15}$$

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202009_6(9).0008

4. OPTIMIZATION RESULTS AND ANALYSIS OF NONGJIANG FARM

4.1. Optimization Results of Farm Machinery

The Gauss-Seidel iteration method of Matlab software programming was adopted for the optimization solution, and the operation results satisfying certain error accuracy were finally obtained after several iterations, as shown in the table below table 5:

Table 5. Matlab operation results

Variable	Value	Reduced Cost
X1	201	18547
X2	181	63772
X3	57	21988
X4	84	9805
X5	139	69884
X6	141	115913
X7	0	72093
X8	138	19864
X9	152	17663
X10	128	2813
X11	0	45821
X12	161	5755
X13	234	7737
X14	0	34701
X15	162	8389
X16	81	9673
X17	0	3679
X18	53	23119
X19	0	191122
X20	173	5694
X21	262	2307
X22	164	218719
X23	0	97872
X24	204	73824
X25	391	58639
X26	336	2078
X27	0	11974
X28	251	7892

Table 5 of the above Matlab results is sorted out, and corresponding text explanations are given for each variable. The optimized number of each type of power machine and power machine is obtained, and compared with the current number of power machine and power machine, the following table is obtained:

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Table 6. Comparison of configuration results before and after integer linear model optimization

Number of agricultural machinery	Names of farm machinery and tools	Optimized quantity of agricultural machinery(a)	Quantity of agricultural machinery before optimization(a)
1	Dongfanghong 8-2 tractor	201	234
2	Dongfanghong 492 tractor	181	235
3	Kubotian M954K tractor	57	83
4	Kubotian 1204 wheeled tractor	84	111
5	Regular CF809 harvester	139	147
6	Waud 3-48 harvester	141	206
7	Waud 3-72 harvester	0	39
8	The Wald 391 harvester	138	184
9	Donghong 135 puddling machine	152	203
10	Dongfanghong 459 puddling machine	128	194
11	Open king 1-3 puddling machine	0	29
12	Kai Xuan King C-109 puddling machine	161	157
13	Fukuda puddling machine	234	277
14	Kubotian 430 rice transplanter	0	47
15	Jiubaotian 257 rice transplanter	162	233
16	Yangma 3-92 rice transplanter	81	139
17	Yangma 8-42 rice transplanter	0	26
18	Ward 37 rake	53	71
19	Wold 71-6.35 Hay rake	0	49
20	Foton 1004 Rake	173	226
21	Dill's rake	262	306
22	Fukuda 79 Hay rake	164	217
23	6-30 paddy field plough	0	23
24	6-27 paddy field plough	204	269
25	5-27 paddy field plough	391	463
26	Crass baling machine	336	392
27	Mighty 4-75 baling machine	0	27
28	Whammy 8-358 bundling machine	251	292

The above agricultural machinery configuration table before and after optimization by the integer linear programming model is drawn as a line diagram, and the drawing results are shown in the figure below:

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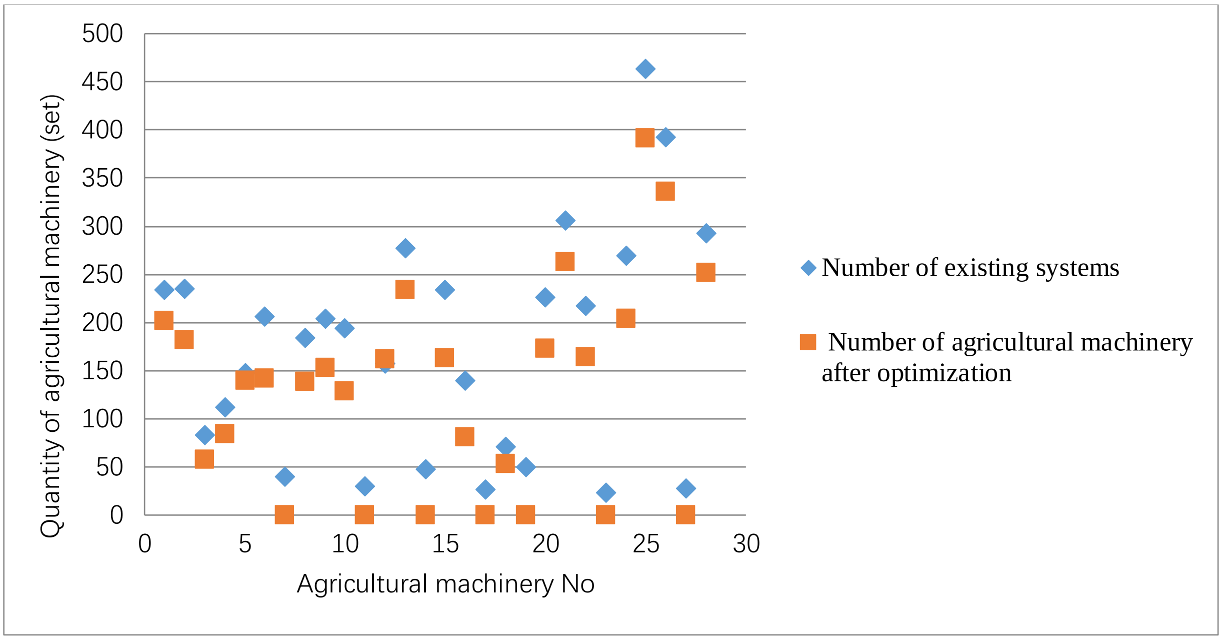

Figure 1. Comparison of farm machinery allocation before and after farm optimization

From the point of the line chart of the above, we can be more intuitive to see clearly, the optimized with a total of seven ordinate zero points, namely after optimization to solve the integer linear programming model, in the case of finish the farm work, the farm has reduced the seven kinds of existing agricultural machinery farm equipment, is currently the number of farm machinery in super saturation state, and each machine there is a waste, does not make the machine efficiently play its role fully, so the farm now don't need to add the number of agricultural machinery. At present, there is unreasonable distribution of farm machinery and equipment, waste of funds, you can get rid of the excess machinery, save resources to more needed places. Therefore, it is of great significance for this paper to use integer linear programming model to conduct modeling research on The Nongjiang farm in Reclamation area of Heilongjiang to find the optimal solution.

After summing up the number of agricultural machinery of various types in The Farm corresponding to Table 6, the comparison table of the total number of machines and the benefits of the total cost before and after optimization by the integer linear programming model is obtained, as shown in the following table:

Table 7. Comparison of benefits before and after optimization

The serial number	Economic indicators	Before optimization	The optimized	Comparison before and after optimization
1	Quantity of agricultural machinery (a)	4879	3693	-1186
2	Total annual cost (Ten thousand yuan)	8916.55	6783.41	-2133.14
3	The cost per unit (yuan /hm^2)	2549.28	1934.36	-614.92

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From the comparison table of the total benefits before and after the optimization of farms in Table 7, we can see that the optimization results have reduced the total number of agricultural instruments in The Farm by 1,186, reduced the cost of agricultural land by 614.92 yuan per hectare, and saved the total operating cost by 21,331,400 yuan.

4.2. Error Analysis of Farm Results

Let X(k) be the approximation, X* the initial value, and B the iterative matrix.

By error estimation formula:

$$\left\|X^{(k)} - X^{*}\right\| \leq \frac{\|B\|^{k}}{1 - \|B\|}\left\|X^{(1)} - X^{(0)}\right\|, k = 1, 2, 3, \cdots \tag{16}$$

And the approximate solution is required $X^{(k)}$ The error of the:

$$\left\|X^{(k)} - X^{*}\right\| \leq 10^{-4} \tag{17}$$

According to the error estimation formula, as long as the number of iterations K satisfies:

$$\frac{\|B\|_{\infty}^{k}}{1 - \|B\|_{\infty}}\left\|X^{(1)} - X^{(0)}\right\| \leq 10^{-4} \tag{18}$$

The number of Jacobi iterations is calculated by the program code. Therefore, the number of iterations using Jacobi method is 58 times. The number of Gauss-Seidel iterations is 29.

5. CONCLUSION

In this paper, the values of the required variables are obtained by searching a large amount of original data and computing them. Then, through the comprehensive research and analysis of a large number of literatures and the consideration of various aspects and all directions, the optimal objective function is obtained and four inequality equations of operation quantity constraint, power machine equipped constraint, operation machine equipped constraint and non-negative constraint are further established in combination with the actual situation. Finally, the gauss-Seidel iterative method of Matlab programming is used to calculate the optimal solution. Matlab programming was used to solve the problem to make the results more accurate, which provided a reasonable theoretical basis for the whole process of mechanization that could effectively arrange production operations in the future. The research on optimal allocation of agricultural machinery not only saved resources, but also promoted agricultural modernization more efficiently. It provides a great reference value for the research on the equipping problem.

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