Optimization of industrial structure configuration based on fruit fly optimization algorithm

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Abstract

Establishing the mathematical optimization model of Shangqiu's agricultural structure from three aspects - economy, ecology and society, the agricultural industry structure in Shangqiu is regarded as the research object, utilizing fruit fly optimization algorithm to solve the mathematical model. Simulation results show that fruit fly optimization algorithm can solve the optimal solution for Shangqiu's agricultural industry structure to achieve the maximum benefits, thus providing the decision-making basis for adjustment and development of Shangqiu's agricultural structure.

Keywords: fruit fly optimization algorithm, industrial structure, optimization model, population size, iterations

1 Introduction

Shangqiu has a large population, little land, fragile ecological environment, farmers with low cultural quality, poor economy and improper industry positioning which lead to the unfavorable development of poverty reduction in the region. There are a large proportion of absolute poor population in Shangqiu, and backward is still the reality of this region. Based on 2012-2020 poverty reduction program of Henan Province, Shangqiu, for example, will build mathematical model for the agricultural structure in the region from aspects of economy, ecology and society, utilize fruit fly optimization algorithm for multi-objective optimization solution and achieve the optimal allocation in Shangqiu's agricultural structure, thereby providing decision-making basis for the development of agricultural industry structure in Shangqiu area [1-7].

2 Fruit fly optimization algorithm

2.1 OVERVIEW OF FRUIT FLY OPTIMIZATION ALGORITHM

Fruit fly optimization algorithm is a new group intelligence algorithm proposed by Pan Chao [8] in 2011. Fruit flies can detect food source on the air through their olfactory and visual superiority, and after detecting the food, they use acute vision to locate food and companions, and fly toward the food. The method is to deduce a new way to realize global optimization based on the foraging behavior of Fruit flies. Fruit fly optimization process is shown in Figure 1.

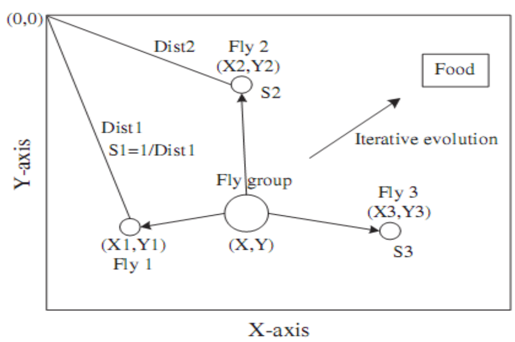

FIGURE 1 Optimization roadmap of fruit fly group

2.2 STEPS OF FRUIT FLY OPTIMIZATION ALGORITHM

Fruit fly optimization algorithms can be divided into seven steps as follows.

1) In Figure 1, the position initialization result of fruit fly group is $Init\ X\_axis$ and $Init\ Y\_axis$.

2) After setting the search direction RV_x and RV_y, random search distance of single fruit fly can be obtained by the following Equation:

$$Yi = Init\ Y\_axis + RV_y . \quad (1)$$

3) The distance from the origin to the current position of fruit fly is estimated a $Xi = Init\ X\_axis + RV_x$ a $Disti$, and the smell concentration is estimated according to Equation (2), which is equal to the reciprocal of the distance.

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$$Disti = \sqrt{Xi^2 + Yi^2}$$
$$Si = 1/Disti \quad (2)$$

4) The result of Equation (2) is substituted into Equation (3), the determination function of smell concentration, thus calculating the smell concentration value corresponding to the current position of individual fly.

$$Smelli = Function(Si)\,. \quad (3)$$

5) Best smell concentration of fruit fly group can be obtained by the following Equation

$$[bestSmell\ bestIndex] = \max(Smelli)\,. \quad (4)$$

6) Best smell concentration of fly group and the corresponding *x* and *y* coordinates are retained, and the fly group flies toward the food source through visual positioning.

$$Smellbest = bestSmell$$
$$X\_axis = X(bestIndex) \quad (5)$$
$$Y\_axis = Y(bestIndex)$$

7) Steps from 2) to 5) are repeated, and the smell concentration is judged. If a better smell concentration is obtained, go to Step 6); otherwise, iterative optimization will be executed.

3 Modeling

3.1 BOUNDARY DETERMINATION

The agricultural industry structure in Shangqiu is selected as the study object with 2012 as the planning year, and the study mainly focuses on the relationship between agriculture, forestry, animal husbandry and fishery, thus conducting the simultaneous layout optimization on the internal structure of crop farming and animal husbandry and achieving coordinated and sustainable development of different industries. Due to complex industrial structure in the region, different industries cannot be studied through a careful division, so a lot of data in the model are replaced by the average values [9,10].

3.2 DECISION VARIABLES

The planting area of selected major crops and cash crops in Shangqiu is X_{1j} (Ten thousand hm2), where rice X_{11}, wheat X_{12}, corn X_{13}, soybeans X_{14}, millet X_{15}, sorghum X_{16}, potato X_{11}, oil plant X_{18}, beet X_{19}, flax x_{110}, tobacco X_{111}, vegetable X_{112}, melon and fruit X_{113}, forage grass X_{114} and forage crop X_{115}. Forage grass and forage crop are regarded as a study entirety. In animal husbandry, the decision variable X_{2j} includes five variables: beef X_{21}, dairy cattle X_{22}, pig X_{23}, sheep X_{24} and poultry X_{25}. Forestry and aquaculture industry are regarded as a study entirety, where woodland area is X_3 (Ten thousand hm2) and the total aquaculture area is X_4 (Ten thousand hm2).

3.3 OBJECTIVE FUNCTION

Objective function $E(x)$ indicates the sum net income of various industries. And in crop farming, net income is the product of net output per unit area and total acreages; the expression of net income in animal husbandry can be obtained through the method of best square approximation [11-13]. The relationship between net income and feeding amount can be expressed by the linear weighted sum of logarithmic function $y = a\ln(1+bx)$ and logistic curve $y = \frac{a^*}{1+b^*e^{-cx}}$, where *x* indicates the feeding amount, and *y* indicates the net income; net incomes of forestry and aquaculture farming are similar to that of crop farming, which can be approximated as a linear function. Therefore, the objective function can be expressed as follows.

$$\begin{aligned}
\max\ E(x) &= 5547.8X_{11} + 1505X_{12} + 1622X_{13} + 2359X_{14} + 1287.2X_{15} + \\
&1248.4X_{16} + 1197.7X_{17} + 1220X_{18} + 1116.3X_{19} + 4078.8X_{110} + 3173.7X_{111} + \\
&8464.8X_{112} + 18176X_{113} + 2665X_{114} + 1472X_{115} + \frac{442850}{1+65.4e^{-0.0121X_{21}}}\times 0.63 + \\
&572404\ln(1+0.0017X_{21})\times 0.37 + \frac{588940}{1+162.2e^{-0.077X_{22}}}\times 0.61 + 6829556\ln(1+0.0006X_{22})\times 0.39 \\
&+ \frac{269450}{1+78.9e^{-0.0049X_{23}}}\times 0.89 + 3601713\ln(1+0.0002X_{23})\times 0.11 + \frac{82100}{1+19.6e^{-0.0071X_{24}}}\times 0.81 + 99598\ln(1+0.0007X_{24})\times 0.19 \\
&+ \frac{473800}{1+17.6e^{-0.0004X_{25}}}\times 0.92 + 1564320\ln(1+0.000019X_{25})\times 0.08 + 67X_3 + 4152X_4
\end{aligned} \quad .(6)$$

Due to the fundamental status of soil in agricultural production, soil nutrient and moisture have direct impact on crop growth, animal husbandry development and the expansion of aquaculture area, so the content of organic matter in soil is regarded as an important decision variable. In this research, the difference $\delta(x)$ between the current content and balance content of organic matter in the soil is an important indicator of soil fertility, while influencing factors including the status of soil, water conservation and vegetation cover are regarded as constraints. The organic matter content in the soil is predicted and evaluated through Jenny mathematical model, wherein the topsoil depth is 0.2mm [14-16].

$$\begin{aligned}&\min\ \delta(x) = 0.04 - \frac{1}{0.0564\times 225\times(\sum_{j=1}^{15} X_{1j} + X_3)}([0.6\times(2.25(X_{21}+X_{22})+\\&1.5X_{23}+0.52X_{24}+0.015X_{25})+3908.8\times 0.108\times 0.5]\times 0.512+[0.3\times(9X_{11}+\\&4.19X_{12}+11.14X_{13}+2.36X_{14}+3.08X_{15}+8.24X_{16})+2.175X_{11}+0.838X_{12}+\\&0.502X_{13}+0.41X_{14}+0.533X_{15}+0.412X_{16}]\times 0.203)\times(1-e^{-0.0564\times 6})-0.0317e^{-0.0564\times 6}\end{aligned}, \quad (7)$$

$$\begin{aligned}&\min\ D_\delta(x) = ([3200-0.9\times(7.5X_{11}+2.99X_{12}+5.57X_{13}+2.05X_{15}+4.12X_{16})+\\&650-0.9\times 2.05X_{14}]+1800-30.38X_{112})\times 0.72+[450-(0.198X_{21}+\\&0.089X_{23}+0.015X_{24}+0.0019X_{25})+1250-3.8X_{22}+160-0.0044X_{25}+75-0.98X_4]\times 0.28\end{aligned}. \quad (8)$$

3.4 CONSTRAINTS

1) Natural resource constraints. The constraint of total available land area:

$$\sum_{j=1}^{15} X_{1j} + X_3 + X_4 \le 3758.7. \quad (9)$$

The constraint of arable land resource:

$$\sum_{j=1}^{15} X_{1j} \le 1180. \quad (10)$$

2) Acreage constraint. Aquaculture area constraint:

$$X_4 \ge 40. \quad (11)$$

Economic crop acreage constraint:

$$\sum_{j=1}^{13} X_{1j} \ge 220. \quad (12)$$

Forage crop acreage constraint:

$$X_{114} + X_{115} \ge 30. \quad (13)$$

3) Ecological constraint. Constraint of organic fertilizer amount: the total amount of required fertilizer for various crops and waste fertilizer should not exceed the amount of provided fertilizer.

$$\begin{aligned}&4.875X_{11}+2.792X_{12}+4.137X_{13}+1.822X_{14}+\\&1.936X_{15}+2.725X_{16}+1.439X_{17}+3.12\sum_{j=1}^{15}X_{1j}\\&+8.274X_{112}+2.17X_{113}+1.19X_3 \le 2.25(X_{21}+X_{22})\\&+1.5X_{23}+0.52X_{24}+0.015X_{25}+3908.8\times 0.108+\\&9X_{11}+4.19X_{12}+11.14X_{13}+2.26X_{14}+3.08X_{15}+\\&8.24X_{16}+2.175X_{11}+0.838X_{12}+0.502X_{13}+\\&0.41X_{14}+0.533X_{15}+0.412X_{16}\end{aligned}. \quad (14)$$

Green coverage constraint:

$$X_3 \ge 0.42\times 4546. \quad (15)$$

4) Demand constraint. Grain output constraint:

$$\begin{aligned}&7.50X_{11}+2.99X_{12}+5.57X_{13}+2.05X_{14}+\\&2.05X_{15}+4.12X_{16} \ge 300036\end{aligned}. \quad (16)$$

Meat output constraint:

$$0.198X_{21}+0.089X_{23}+0.015X_{24}+0.0063X_{25} \ge 400. \quad (17)$$

Vegetable output constraint:

$$30.38X_{112} \ge 1200. \quad (18)$$

Constraint of required roughage for the development of animal husbandry:

$$\begin{aligned}&(9X_{11}+4.19X_{12}+11.14X_{13}+2.26X_{14}+\\&3.08X_{15}+8.24X_{16})\times 0.23+4.12X_{114}+\\&600\times 1.41 \ge 1.51X_{21}+3.42X_{22}+0.054X_{24}\end{aligned}. \quad (19)$$

Constraint of concentrated feed demand:

$$\begin{aligned}&(0.128X_{21}+1.065X_{22}+0.19X_{23}+0.022X_{24}+\\&0.015X_{25}+0.432X_4)\times 0.5 \le\\&0.1\times(7.50X_{11}+2.99X_{12}+2.05X_{14}+2.05X_{15}+\\&4.12X_{16}+3.19X_{17})+0.4\times 5.57X_{13}+4.54X_{115}\end{aligned}. \quad (20)$$

Minimum quantity of dairy cattle:

$$X_{22} \ge 260. \quad (21)$$

Non-negative constraint of decision variables:

$$X_{ij} \ge 0\ \ (i=1,2,3,4). \quad (22)$$

4 Solutions for these problems

MATLAB software is utilized as research platform for solving the simulation model of agricultural structure in Shangqiu, China, with the results shown in Table 1, Figure 2, Figure 3 and Figure 4.

TABLE 1 "Optimal solution" of agricultural structure optimization

Variable	Optimization value
X_{11}	154.66
X_{14}	295.04
X_{17}	28.617
X_{110}	42.299
X_{113}	26.356
$X2_{1}$	500
X_{24}	1212.8
X_{4}	50.609
$D_{\delta}(X)$	855.71
X_{12}	40.00
X_{15}	8.238
X_{18}	68.483
X_{111}	25.948
X_{22}	320.5
$E(X)$	604.32
X_{13}	198.56
X_{16}	12.972
X_{19}	23.077
X_{121}	57.509
X_{115}	29.452
X_{23}	2898.5
X_{3}	2378.4
$\delta(X)$	0.0008

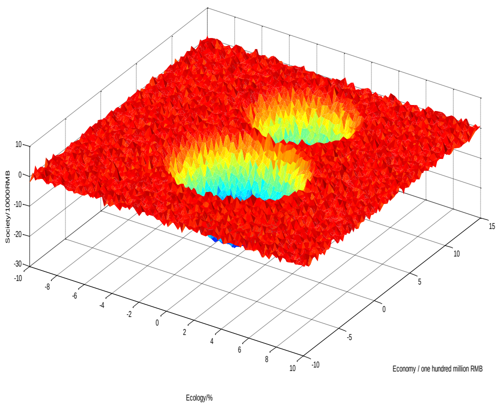

FIGURE 2 Pareto frontier of agricultural structure model

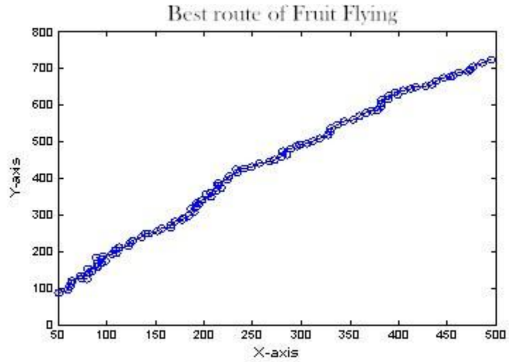

FIGURE 3 Optimization roadmap of fruit fly optimization algorithm

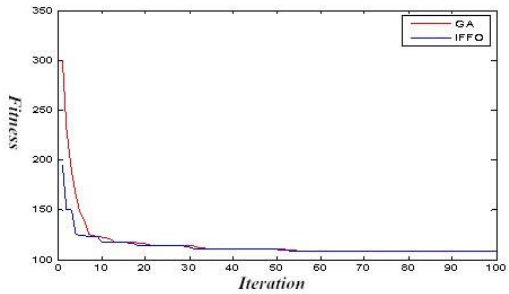

FIGURE 4 Results comparison between fruit fly optimization algorithm (IFFO) and genetic algorithm (GA)

Figure 4 indicates that fruit fly optimization algorithm has a faster convergence and better optimization ability than that of genetic algorithm, which proves the superiority of the proposed algorithm.

5 Conclusions

In this research, based on the coordinating research in three aspects – economy, ecology and society, multi-objective optimization model of agricultural industry structure in Shangqiu is established, and fruit fly optimization algorithm is utilized for solving the multi-objective optimization model, thus optimizing the objecttive functions in different degrees; meanwhile, multi-index evaluation is carried out on the optimization results, which greatly enhances and improves the coordinated and sustainable development of Shangqiu's agricultural industry structure through fruit fly optimization algorithm.

Researches on industrial structure allocation through fruit fly optimization algorithm have important theoretical and practical significance on agricultural structure adjustment and allocation in Shangqiu, China. And some competitive industries can be developed based on the optimization results, such as increasing the acreage of rice and soybean; economic and forage crops should be mainly developed on the basis of ensuring food security; livestock and dairy products, returning rate of organic fertilizer and soil fertility should be enhanced; besides, local government needs to vigorously develop green food and explore potentials in agricultural industry.

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