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Research Article

Optimal Matching Metaheuristic Algorithm for Potential Areas of Agricultural Economic Resources Development Based on Spatial Relationship

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The agriculture sector is the backbone of the economies of many Asian countries such as India, China, and Bangladesh. The agriculture sector can contribute a major share to the GDP of such countries where the main occupation of the citizens is agriculture or the dependency of the citizens is mainly on the agricultural productivity. It is important to study the potential areas of agricultural economic resource development. The existing methods are not efficient enough to map the potential areas of agricultural productivity with economic resource development, and hence, it has motivated us to study the aspects which impact the economic resource development based on agricultural productivity. There are numerous factors such as low productivity, high irrigation amount, high labor charges, low proportion of planning optimization, and low crop yield that should be considered to study the correlation between economic development and agricultural productivity. Firstly, the spatial relationship of potential areas of agricultural economic resources development is analyzed in this paper. Secondly, the multiobjective linear programming model is proposed. Based on this multiobjective model, the optimal matching model for potential areas of agricultural economic resource development is constructed, and the improved genetic algorithm is used to solve the model to realize the optimal matching of potential areas of agricultural productivity and economic resource development. The experimental results show that the proposed method has high economic benefit, low irrigation amount, and high proportion of planning optimization with high crop yield.

1. Introduction

Water resource is an important factor for promoting agriculture-based economic growth and agriculture is the largest water resource consumer in China [1]. Due to the influence of market price and water consumption of different crops, different allocation of water resources among crops can bring different economic benefits [2]. In order to make the full utilization of water resources and achieve the maximum benefit, it is necessary to adjust the crop planting structure with differently available agricultural water resources [3]. Water resources are needed for ensuring regional food security and a reasonable output structure of crop products [1]. Especially for the arid and semiarid areas, it is of great practical importance for regional agricultural development to adjust the regional planting structure under the constraints of limited agriculturally available water resources. Other resources are also important, but not as much as those of water resources. Soil quality, humidity for plants, weather conditions, climate, exposure to sunlight, pesticides, quality of seeds, temperature, economic markets, and export-import policies all contribute as factors of influence on agricultural productivity. The motivation of this paper is to study the impact of these factors on agricultural productivity and the correlation between agricultural productivity and economic resource development.

In [4], the authors proposed a matching algorithm for resource development potential regions based on linear programming. The algorithm took the highest economic benefit under different irrigation technology proportions as the goal and added the calculation of a comprehensive ecological environment index to the conventional constraints such as total agricultural planting area and water consumption of agricultural planting. Based on this, the ecological benefit of optimization results was evaluated, and a linear programming model was established. To achieve area matching, the algorithm did not consider the crop planting structure and had the problem of low proportion of planning optimization. In [5], the authors proposed a matching algorithm for potential regions of agricultural resource development based on IBM software. Wheat, corn, cotton, rice, sugar beet, and potato were selected as the research objects. On the basis of using the Penman–Monteith formula to calculate the unit virtual water yield of 6 main crops in 14 prefectures and 64 main producing counties in Xinjiang, the algorithm proposed a matching algorithm for potential regions of agricultural resource development based on IBM SPSS software and the unit virtual water value of main crops was obtained. With the help of IBM SPSS for correspondence analysis, this paper studied the planting preference and layout of main crops in Xinjiang from the perspective of virtual water value. The algorithm did not consider the water consumption of agricultural plantings and had the problem of high irrigation water. In [6], the authors proposed an area matching algorithm for agricultural resource development potential based on multitemporal Sentinel-2A. The algorithm used multitemporal Sentinel-2A remote sensing images as a data source and calculated the time series normalized vegetation index (NDVI) and red edge normalized vegetation index (RBNDVI) and their combination characteristics. It analyzed crop characteristic curves and used the random forest method to match five characteristic parameters as classification characteristics. The algorithm did not consider the yield and benefit and had the problems of low economic benefit and low crop yield.

In [7], the authors explored the usage of IT and its applications in the area of agriculture. The role of IT in the development of agricultural productivity and its impact on the economy were studied in the paper. It certainly helped the agriculture sector to improve its traditional way of doing things and in adding more value to the country's economy. In [8], the authors concluded that the contribution of agriculture in GDP was decreasing significantly over the periods with the evolution of manufacturing and other industries. The economy was still growing due to the agriculture sector and could collapse if the agriculture sector was ignored. The importance of agricultural products would prevail in the growth of the economy. In [9], the authors studied the impact of outdated irrigation methods adopted by the farmers in small villages. The lack of knowledge led to the generation of poor income due to the adoption of obsolete methods for irrigation and agriculture. Economic growth and food security were concerned with the yield of crops. The major issue of poverty was revealed to be poor irrigation methods. In [10], the authors presented a structural model which revealed the direct and indirect impact of dam-driven water for irrigation on the revenue of the crops. The results concluded that the revenue was directly proportional to the availability of water. The availability of water could aid in generating high revenues.

Apart from water resources, we have made an attempt to study more factors that affect productivity and economic resource development. The major highlights are given as follows:

(i) There are numerous factors such as low productivity, high irrigation amount, high labor charges, low proportion of planning optimization, and low crop yield which are considered to study the correlation between economic development and agricultural productivity in this paper rather than focusing on just one factor like water/irrigation resources.

(ii) In the first phase, the spatial relationship of potential areas of agricultural economic resources development is analyzed to get an idea about the factors influencing agricultural productivity and economic growth.

(iii) Then, the multiobjective linear programming model is proposed. The multiobjective model considers constraints and optimizes multiple objectives simultaneously.

(iv) Based on the multiobjective model, the optimal matching model for potential areas of agricultural economic resource development is constructed, and the improved genetic algorithm is used to solve the model to realize the optimal matching of potential areas of agricultural productivity and economic resource development.

The paper discusses the proposed model in two phases, and the next section explains the proposed model. The third section focuses on the results of the proposed research. The last section summarizes the research work presented in this paper.

2. Proposed Research

This section explains the best match model for the potential area of agricultural economic resources development.

2.1. The Proposed Mapping Model for Agricultural Productivity and Economic Resources. Based on the spatial relationship, the optimal matching algorithm for the potential area of agricultural economic resources development considers the spatial relationship between the development potential areas and constructs the optimal matching model for the potential area of agricultural economic resources development through three submodels as discussed below.

(1) The multiobjective optimal allocation model of flow and time in main and branch canals is constructed, and the two objectives of minimum fluctuation of water distribution flow and minimum loss of water conveyance are realized at the same time.

(2) Branch canal and bucket canal's round irrigation group division model are constructed to minimize

water distribution time and obtain the distribution flow and time of branch canal and bucket canal, thereby obtaining optimized water distribution.

(3) Based on the results of water distribution in main and branch canals, a linear fractional programming model based on chance-constrained programming is constructed to optimize the planting structure of various crops in an irrigation area, so as to obtain the maximum benefit per unit planting area.

The specific process is shown in Figure 1.

2.1.1. Multiobjective Linear Programming Model of Flow and Time Allocation in Canal System. The branch canals are known as continuous irrigation channels. Water is available in the canals throughout the water distribution cycle in China [11, 12]. The modeling idea of the proposed algorithm is to optimize the flow and water distribution time of the main and branch channels in the irrigation area and satisfy the following clauses:

(1) The actual water distribution is within the range of available water in the irrigation area.
(2) The water distribution time is within the specified rotation period.
(3) The actual water distribution should meet the requirements of crop irrigation.
(4) At any time, the sum of the water distribution flows of each lower channel is equal to the water distribution flows of the upper channel, and the water distribution flow of the upper and lower channels should be changed between 0.6 and 1.2 times the design flow as far as possible, so as to meet the requirements of the water distribution level of the channel and prevent the collapse caused by the overflow of the channel. According to the above modeling idea, a multiobjective linear programming model for water distribution in main and branch canals is constructed. The first objective function is to consider the minimum fluctuation of water distribution flow in superior canals at different times; the second objective function is to minimize the water loss of the canal system, which can reflect the actual situation of the canal system to meet the requirements of the canal system.

The objective function (1) of the model is given by equation (1) and the substitute is devised by equation (2).

Objective function (1) is given as follows:

$$\min Z_1 = \min \frac{\sum_{t=1}^{T} \left(Q_{st} - \overline{Q}_s\right)^2}{T-1}, \quad \forall t = 1, 2, \ldots, T, \tag{1}$$

where

$$Q_{st} = \sum_{n=1}^{N} q_n^* f_{tn}(x), \quad \forall t = 1, 2, \ldots, T. \tag{2}$$

Objective function (2) is given by equation (3) and the substitute is devised by equation (4).

$$\min Z_2 = V_s + V_d = \frac{\sum_{t=1}^{T} W_{st}\left(1-\eta_s\right)}{\eta_s} + \sum_{t=1}^{T} W_{dn}^*\left(1-\eta_{dn}\right). \tag{3}$$

Where,

$$\begin{cases} W_{st} = Q_{st} t_{st} \times 60 \times 60, \\ W_{dn}^* = q_n^* \times t_{1n} \times 60 \times 60. \end{cases} \tag{4}$$

The constraints of the multiobjective method are shown from equations (5) to (8).

The constraint of irrigation water supply is given in the following equation:

$$\frac{W_{st}}{\eta_s} \le W_{at}, \quad \forall t = 1, 2, \ldots, T. \tag{5}$$

A round constraint is given by the following equation:

$$\begin{cases} 0 \le t_{0n} \le T, \\ t_{2n} \le T, & \forall t = 1, 2, \ldots, T. \\ t_{0n} + t_{1n} = t_{2n}, \end{cases} \tag{6}$$

A flow constraint of lower channel is given in the following equation:

$$a \times qd_n \le q_n^* \le qd_n, \quad \forall t = 1, 2, \ldots, N. \tag{7}$$

Flow constraints of superior channel node are given in the following clubbed equation:

$$\begin{cases} \text{Node } A\text{: } aQ_A \le \sum_{n=1}^{N} q_n^* f_{tn}(x) \le bQ_A, & \forall n = 1, 2, \ldots, N, \\ \text{Node } B\text{: } aQ_B \le \sum_{n=1}^{N} q_n^* f_{tn}(x) \le bQ_B, & \forall n = 1, 2, \ldots, 5, \\ \text{Node } C\text{: } aQ_C \le \sum_{n=1}^{N} q_n^* f_{tn}(x) \le bQ_C, & \forall n = 6, 7, \ldots, N, \\ \text{Node } D\text{: } aQ_D \le \sum_{n=1}^{N} q_n^* f_{tn}(x) \le bQ_D, & \forall n = 6, 7, \ldots, 15, \\ \text{Node } E\text{: } aQ_E \le \sum_{n=1}^{N} q_n^* f_{tn}(x) \le bQ_E, & \forall n = 16, 17, \ldots, 19. \end{cases} \tag{8}$$

In the above equations, t is the time, n is the number of lower-level channels, N is the number of branch canals in a round irrigation group, q_n^* is the gross distribution flow of the lower-level channels of each round irrigation group, t_{0n} is the start time of the n th lower-level channel, t_{1n} is the irrigation time of the n-th lower-level channel, t_{2n} is the irrigation end time of the n th lower-level channel, and n is the time step of the t th period. T is the rotation irrigation cycle and Q_{st} is the net water distribution of the upper-level channel at time t which is equal to the sum of the flow of the lower-level water distribution channel at this moment.

$f_{tn}(x)$ is a continuous function that describes the continuous water distribution state of the channel during the

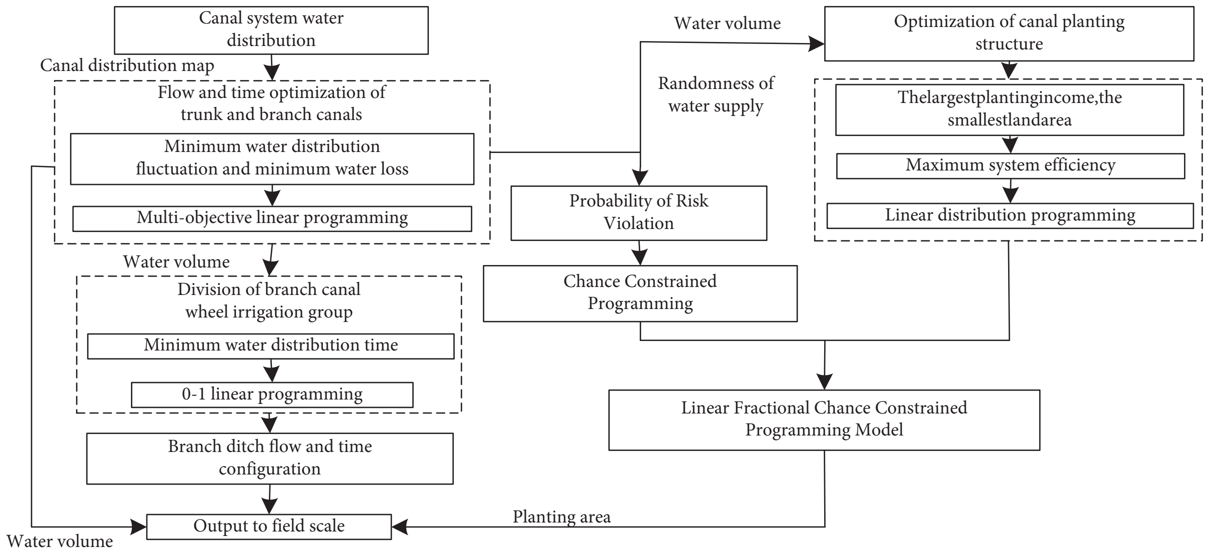

Figure 1: Schema of the proposed research.

rotation period. If $t_{0n} \leq t \leq t_{2n}$, then $f_{tn}(x) = 1$, otherwise, $f_{tn}(x) = 0$; W_{st} is the net water distribution of the upper-level channel, W^*_{dn} is the gross water distribution of the n th lower channel; η_s is the water utilization coefficient of the upper channel canal system; η_{dn} is the water utilization coefficient of the n th lower channel; qd_n is the design flow rate of the n th lower channel. Q_A, Q_B, Q_C, Q_D, and Q_E are the design flow of the superior channel corresponding to each node A, B, C, D, and E respectively. a and b are the allowable threshold coefficients of channel running flow, respectively, and W_{at} is the water available for irrigation in time period of t.

2.1.2. Optimization of Crop Planting Structure. The optimization of crop planting structures on the scale of a canal system is to study the proportion of crop planting in each canal through a reasonable arrangement to reduce irrigation water demand and increase irrigation income [13, 14]. The research on the deterministic model of crop planting structure optimization at home and abroad includes single-objective models and multiobjective models. The single-objective models generally aim to maximize the economic benefits of the whole irrigation area, and the calculation method generally adopts the linear programming method [15]. The single-objective model is relatively simple, but it fails to achieve the overall development of negotiation and coordination between decision-makers and models [16, 17]. With the concept of sustainable development in irrigation areas, many scholars began to study the multiobjective planning model of crop planting structure [18]. The commonly used multiobjective optimization methods for planting structure include the objective weight method, grey analysis, compromise constraint, fuzzy optimization theory, and order degree mode [19]. These studies have a certain guiding significance for the adjustment of crop planting structures, but most of the multiobjective models of crop planting structures based on the above methods have subjective factors in the calculation of coefficient and the determination of index weight of the objective function [20]. In order to overcome the above shortcomings, the proposed algorithm introduces fractional programming into the multiobjective optimization model of planting structure. Considering the randomness of available water supply, stochastic change-constrained programming is introduced to construct the multiobjective uncertainty model of the planting structure based on fractional programming and stochastic chance-constrained programming. The expression of the model is given in equation (9) and constraint conditions are given in equations (10) and (11).

Objective function is given as follows:

$$\max f = \frac{\max f_1}{\min f_2} = \frac{\max\left[\sum_{s=1}^{S} C_s Y_s a_s - \mathrm{EC}\right]}{\min \sum_{s=1}^{S} m_s a_s}. \tag{9}$$

Available water constraint is given as follows:

$$\Pr\left\{\sum_{s=1}^{S} m_s a_s - Q_{yl}\right\} \geq 1 - p. \tag{10}$$

Planting area constraint is given as follows:

$$\begin{cases} \sum_{s=1}^{S} a_s \leq A_{\max}, \\ \sum_{s_j=1}^{S_j} a_{s_j} \leq A_{s_j,\max}, a_s \geq a_{s,\min}, a_2 \leq a_{2,\max}, \sum_{s_j=1}^{S_j} a_{s_j} \geq A'_{\min}. \end{cases} \tag{11}$$

In the above equations, f is the objective function, f_1 is the economic benefit target, f_2 is the irrigation water target, s is the crop variety, C_s is the unit price of the s^{th} crop, Y_s is the yield per unit area of the s^{th} crop, a_s is the planting area of the s^{th} crop, a_{s_j} is the planting area of cash crops, and a_2 is the planting area of summer miscellaneous goods. EC is the operational cost of the irrigation area including management fees, maintenance fees, and operating expenses.

m_s is the irrigation quota of the s^{th} crop, Q_{yl} is the net useable water resources of irrigation area, $A_{\max}$ is the maximum total irrigation area of the irrigation area, $A_{s_j,\max}$ and $A'_{\min}$ are the maximum planting area of cash crops and the minimum planting area of food crops respectively, and $a_{s,\min}$ is the minimum planting area of s^{th} crops.

As the above model is a single-layered programming model, there are differences in its solution methods. The solution idea is to transform the single-layer fractional linear programming model into an ordinary linear programming model and then solve it. A typical fractional programming model can be expressed as given in the following equation:

$$\begin{cases} \max f(x) = \dfrac{cx + \alpha}{dx + \beta}, \\ \\ Ax \leq b, x \geq 0. \end{cases} \tag{12}$$

In the above equation, A is a $m \times n$ matrix, x and b are n-dimensional and m-dimensional column vectors, respectively, c and d are n-dimensional row vectors, respectively, and α and β are parameters. If the above formula is satisfied, then the following will applicable.

$d = 0$. $dx + \beta > 0$.

(1) For all x, $dx + \beta > 0$

(2) The objective function is continuously differentiable

(3) The feasible area is nonempty and bounded

Then the above formula can be transformed into the following equation:

$$\begin{cases} \min g(y, z) = z, \\ A^T y + d^T z \geq c^T, \\ -b^T y + \beta z = \alpha, \\ y \geq 0. \end{cases} \tag{13}$$

In the above equation, T represents the transpose of the matrix, y is a column vector with m elements, and z is a scalar. The above formula is a general linear programming model, and its optimal solution $(\hat{y}, \hat{z})$ can be easily obtained. The relaxation column vector $\hat{v}$ is introduced with $\hat{v} = a^T \hat{y} + d^T \hat{z} - c^T$ and $\hat{v} \geq 0$. Let $\hat{x}$ be the optimal solution of model and $\hat{u}$ be the relaxation column vector, then $a\hat{x} + \hat{u} = b$ and $\hat{u} \geq 0$. According to the relaxation theorem, if $\hat{x}_j \hat{v}_j = 0$ and $\hat{y}_j \hat{u}_j = 0$, models (12) and (13) have the same optimal solutions. Therefore, the linear fractional programming model can be solved by the above conversion.

2.1.3. Division Model of Round Irrigation Group in Canal System. The modeling idea has some assumptions. The water flow from the branch canal is determined when the water is distributed to the ditch and the ditch takes the specified amount of water from the branch canal in a constant flow to the required agricultural areas [21]. Once each ditch is opened, it is required to deliver water continuously within the specified time to maintain its stable flow until the specified amount of water reaches the destined place [22]. The result of optimal water distribution is to minimize the leakage loss of the ditch. When dividing each ditch in the branch canal into round irrigation groups, only one ditch in each group is required to divert water [23]. The outlet of any lower ditch is only opened once in the rotation period [24]. When the diversion of the ditch in a group is about to be completed, the diversion flow in the branch canal should be kept unchanged [25]. At this time, the sum of the diversion flow of the ditch plus the leakage loss is in balance with the diversion flow of the branch canal. In order to facilitate the management, the water diversion duration of each round irrigation group is equal or similar.

Taking the minimum irrigation time of a round irrigation group as the objective function, 0-1 integer programming is used to establish the division model of the round irrigation group for branch canal and bucket canal; the constraints such as the maximum net irrigation amount and rotation period are considered. The expression of the model is given in the following equation:

$$\begin{cases} \min Z = \displaystyle\sum_{g=1}^{G} \sum_{m=1}^{M} x_{gm} t_m, \\ \\ t_m = \dfrac{W_{gm} + W_{sm}}{q_{mm}}. \end{cases} \tag{14}$$

In the above equation , Z is the sum of the water delivery time of each round of irrigation group, g is the ordinal number of round irrigation group in branch canal/bucket canal, G is the number of each bucket canal, m is the ordinal number of branch canal/bucket canal, M is the number of round irrigation group, t_m is the water delivery time of each branch canal/bucket canal in the round irrigation group, and W_{gm} is the net water demand of the m^{th} branch canal/bucket canal. W_{sm} represents the leakage loss of the m^{th} branch canal/bucket canal, q_{mm} is the gross flow rate of the m^{th} branch canal/bucket canal, the decision variable is $x_{gm} = \{0, 1\}$ which means the switch state of the m^{th} branch canal/bucket canal of the g th round irrigation group, and x_{gm} is equal to 0, when the branch canal/bucket canal gate is closed. x_{gm} equal to 1 means that the gate of the branch canal/bucket canal is opened. The constraint functions are expressed in equations (15) and (16).

Round constraints are given as follows:

$$T_{\min} \leq \sum_{m=1}^{M} x_{gm} t_m \leq T_{\max}. \tag{15}$$

One time diversion constraint is given as follows:

$$\sum_{g=1}^{G} x_{gm} = 1. \tag{16}$$

0-1 constraints: $x_{gm} = \{0, 1\}$. $T_{\max}$ and $T_{\min}$ are the maximum and minimum diversion time of the upper branch canal.

Combined with the above model, the best matching model of agricultural economic resources development potential is constructed as shown in the following equation:

$$F = \min Z_1 + \min Z_2 + \max f + \min Z. \quad (17)$$

3. Mapping Model for Agriculture Productivity and Economic Development

For mapping the potential area of agricultural economic resources development based on spatial relationship, the improved genetic algorithm (GA) is used to solve the best matching model for the potential area of agricultural economic resources development to achieve the best matching. Specific steps are as follows:

(1) Encoding mode: the encoding mode is using binary encoding.

The coding symbol set used in binary coding is composed of "0" and "1", and the binary symbol string constitutes the individual genotype [22]. Assuming that the value range of a parameter is $[U_{\min}, U_{\max}]$, and the length of the binary code symbol string representing this parameter is l, the corresponding relationship between parameter codes is given by the following equation:

$$\begin{aligned} 000000\cdots000000 &= 0 \longrightarrow U_{\min}, \\ 000000\cdots000000 &= 1 \longrightarrow U_{\min} + \delta, \\ &\vdots \\ 111111\cdots111111 &= 2^l - 1 \longrightarrow U_{\max}. \end{aligned} \quad (18)$$

Then the coding accuracy of binary coding is given by the following equation:

$$\delta = \frac{U_{\max} - U_{\min}}{2^l - 1}. \quad (19)$$

If the code of an individual is X: $a_l a_{l-1} \cdots a_2 a_1$, the corresponding decoding formula is given by

$$x = U_{\min} + \left(\sum_{i=1}^{l} a_i \times 2^{i-1}\right) \frac{U_{\max} - U_{\min}}{2^l - 1}. \quad (20)$$

(2) Initial population: For the generation of the initial population, the random generation method is adopted.

(3) The fitness function is given by the following equation:

$$\text{Fitness} = \begin{cases} \dfrac{1}{1 + \exp\left[\left(f - f_{\text{avg}}\right)/c\right]}, & g \geq 30\% n, \\[2ex] \dfrac{1}{1 + \exp\left(f - f_{\text{avg}}\right)}, & g < 30\% n. \end{cases} \quad (21)$$

f is the original fitness value. If there is a need to find the minimum then f is considered as the objective function. If the problem is to find the maximum then the problem needs to be transformed into a problem of finding the minimum. f_{avg} is the average of the fitness of each individual in the contemporary population. The difference between the f value of each individual and f_{avg} is calculated, g represents the number of individuals whose difference range is (−10, 10), and c represents the magnitude of the maximum absolute value of the difference between the value of f and f_{avg}.

(4) Selection operation: A strategy combining roulette selection and optimal preservation strategy is used to replace the last M individuals in the population after crossover and mutation with the M individuals with the top fitness value in the parent genes, so that the offspring and the parent can participate in the competition together [17].

Implementation steps are as follows:

(a) All the individuals in the current population are ranked according to the fitness value, and M individuals in the front row are selected.
(b) Let all individuals in the contemporary population participate in crossover and mutation operation to produce the next generation population.
(c) All individuals in the next generation population are ranked according to the fitness value, and the next M individuals are found.
(d) The M individuals from 1 is used to replace the M individuals from 3 to produce a new generation.
(e) Crossover operator: A single point crossover operator is used, and the crossover probability is calculated by the following equation:

$$p_c = \begin{cases} p_{c3} - \dfrac{p_{c3} - p_{c2}}{1 + \exp\left[A\left(2 - 3\left(f_{\max} - f'\right)/\left(f_{\max} - f_{\text{avg}} + r\right)\right)\right]}, & f' \geq f_{avg}, \\[2ex] p_{c2} - \dfrac{p_{c2} - p_{c1}}{1 + \exp\left[A\left(1 - 3\left(f_{\text{avg}} - f'\right)/\left(f_{\text{avg}} - f_{\min} + r\right)\right)\right]}, & f' < f_{\text{avg}}, \end{cases} \quad (22)$$

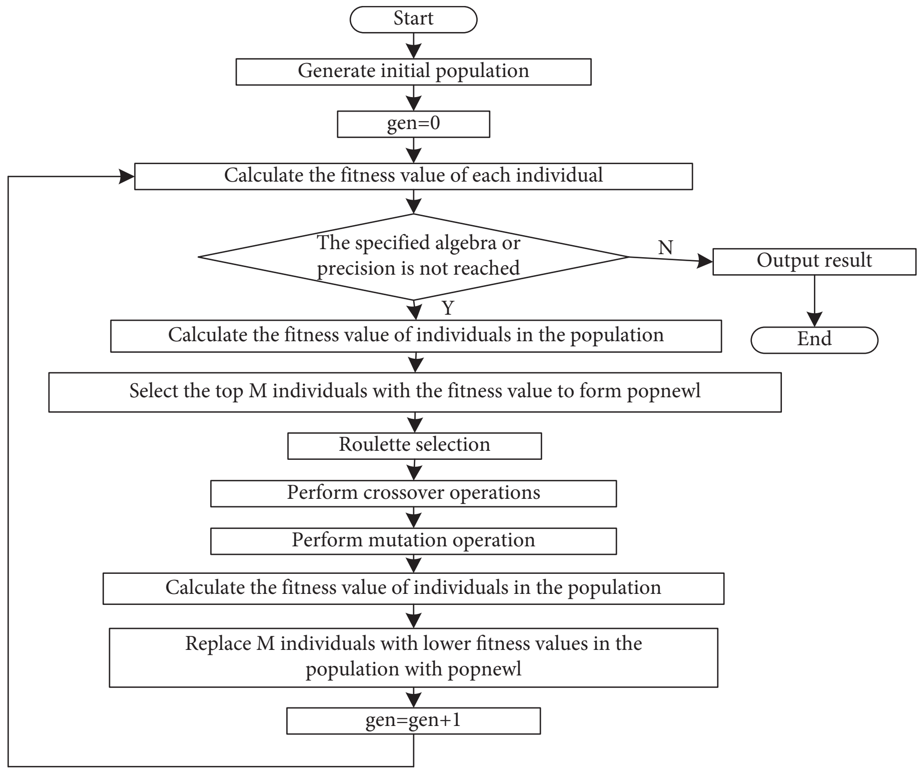

Figure 2: Solution flow using GA.

where, $f_{\max}$ is the largest individual fitness value and $f_{\min}$ is the smallest individual fitness value.

(5) Mutation operator: The basic unit mutation operator is used, and the mutation probability is calculated by the following formula as given in equation:

$$p_m = \begin{cases} p_{m2} - \dfrac{p_{m2} - p_{m1}}{1 + \exp\left[A\left(3\left(f_{\max} - f\right)/\left(f_{\max} - f_{\text{avg}} + r\right) - 2\right)\right]}, & f \geq f_{\text{avg}}, \\ p_{m3} - \dfrac{p_{m3} - p_{m2}}{1 + \exp\left[A\left(3\left(f_{\text{avg}} - f'\right)/\left(f_{\text{avg}} - f_{\min} + r\right)\right) - 1\right]}, & f < f_{\text{avg}}. \end{cases} \tag{23}$$

(6) Set the number of iterations. If the maximum number of iterations is reached, the optimal solution of the best matching model for the potential area of agricultural economic resources development is found. The specific flow chart is shown in Figure 2.

4. Results and Discussion

In order to verify the overall effectiveness of the proposed optimal matching algorithm for the potential region of agricultural economic resources development based on spatial relationships, it is necessary to evaluate the performance and compare it with the other existing methods. The proposed optimal algorithm is termed as “Algorithm 1” in the results. The other comparative approaches considered for the comparative study are algorithm-2 (presented in the reference paper [4]), algorithm-3 (presented in the reference paper [5]), and algorithm-4 (presented in the reference paper [6]). The maximum benefit and minimum irrigation amount of the above algorithms are compared. The test results are shown in Figure 3.

By analyzing the results in Figure 3, it can be seen that compared with algorithm-2 [4], algorithm-3 [5], and algorithm-4 [6], the proposed “algorithm-1” obtains maximum economic benefits in different agricultural areas. On the contrary, the minimum irrigation water requirement by the proposed algorithm is relatively lesser as compared to other approaches. It indicates that algorithm-1 can obtain greater economic benefits with lesser requirements of irrigation water. As Algorithm-1 constructs a multiobjective linear programming model for canal system flow and time configuration, it can obtain greater economic benefits with the lowest amount of irrigation water.

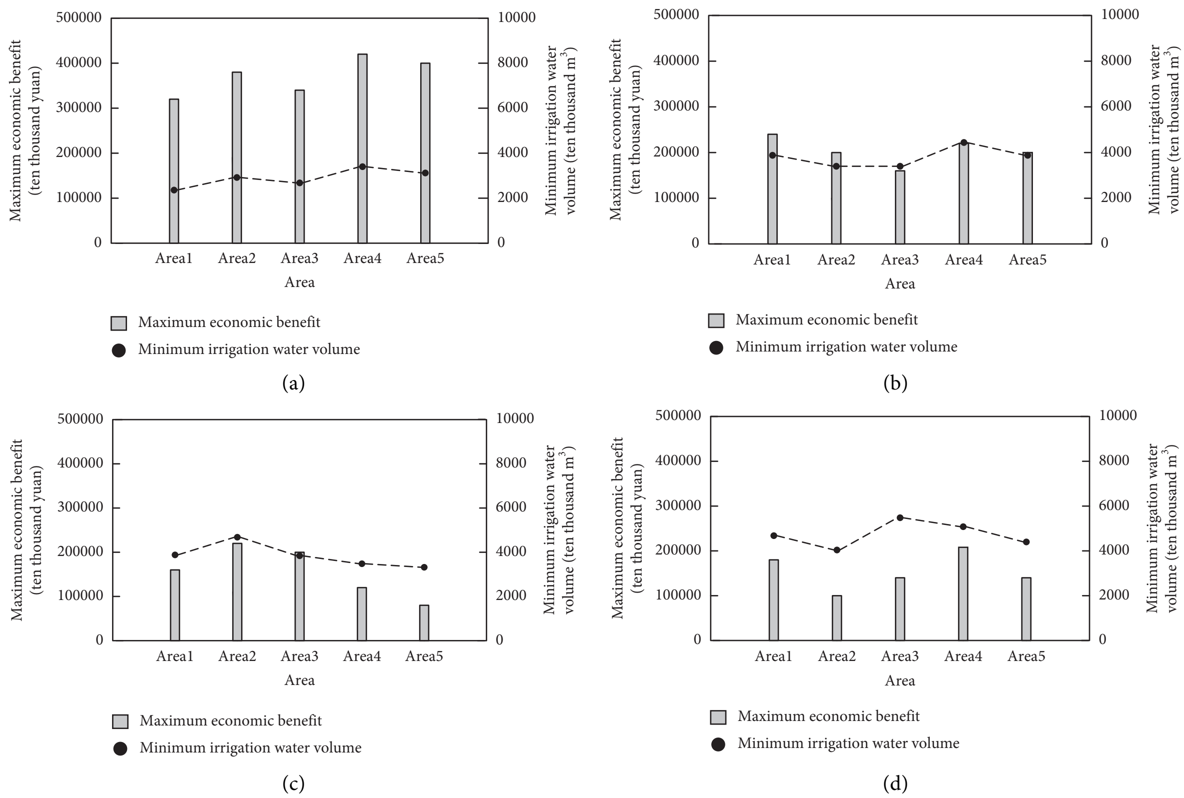

Figure 3: Maximum economic benefit and minimum irrigation water quantity by different algorithms. (a) The maximum economic benefit and minimum irrigation water quantity of algorithm-1, (b) the maximum economic benefit and minimum irrigation water quantity of algorithm-2, (c) the maximum economic benefit and minimum irrigation water quantity of algorithm-3, and (d) the maximum economic benefit and minimum irrigation water quantity of algorithm-4.

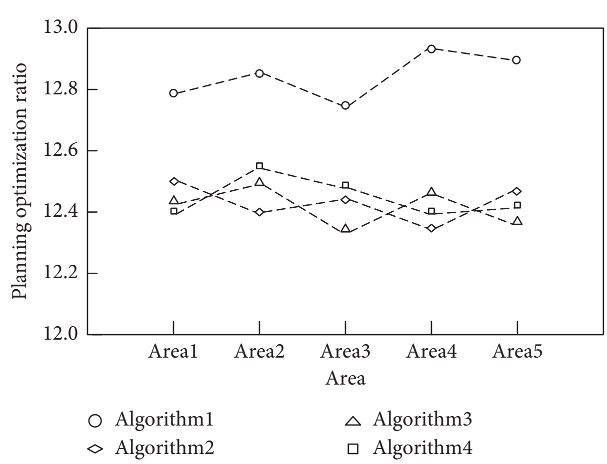

Figure 4: Optimal proportion of different algorithms.

The effectiveness of algorithm-1, algorithm-2 [4], algorithm-3 [5], and algorithm-4 [6] is tested by taking the planning optimization ratio as the test index. The test results are shown in Figure 4.

By analyzing the results in Figure 4, it can be seen that the optimization proportion of algorithm-1 is higher than that of algorithm-2 [4], algorithm-3 [5], and algorithm-4 [6] in different areas. The higher planning proportion is an indicator for the reasonable proportion of crops in the area. From the above analysis, it can be seen that algorithm-1 can effectively and reasonably realize crop allocation in resource development potential areas. Since algorithm-1 constructs a multiobjective uncertainty model of planting structure, it can reasonably allocate the planting areas and areas of different crops in the region and can improve the planning optimization proportion of the algorithm.

The crop yields of algorithm-1, algorithm-2 [4], algorithm-3 [5], and algorithm-4 [6] are shown in Figure 5.

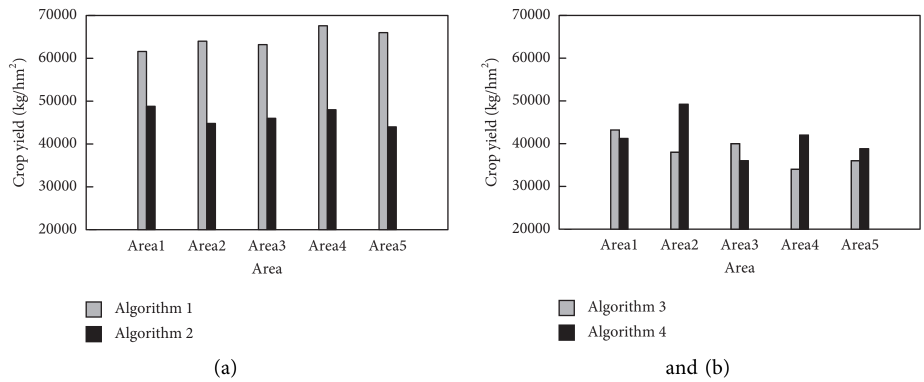

FIGURE 5: Crop yield of different algorithms. (a) Crop yield of algorithm-1 and algorithm-2 and (b) crop yield of algorithm-3 and algorithm-4.

According to the data in Figure 5, the crop yield obtained by the proposed algorithm-1 is much higher than that of algorithm-2 [4], algorithm-3 [5], and algorithm-4 [6] in multiple areas. Since algorithm-1 constructs the division model of the canal system, it optimizes the water distribution, minimizes the leakage loss of the ditch, and improves the regional crop yield.

5. Conclusion

The development of water-saving and efficient agriculture is a strategic choice for sustainable agricultural development. The rational allocation of agricultural water and soil resources is an important way to improve the utilization efficiency of agricultural resources to improve the economic growth of the country. The allocation of agricultural water and soil resources in different spatial scales has different characteristics and impacts on the agriculture produce. Climate change and human activities lead to the uncertainty of optimal utilization of agricultural water and soil resources. Therefore, it is of great significance to study the multiobjective model that can map the agriculture requirements with the available natural resources. The potential growth of agricultural economic resources is certain by devising an intelligent mechanism to map the demand with the available resources and our proposed method is capable of mapping the requirements with the available resources for optimal utilization of agriculture resources for economic development. This paper constructs the optimal mapping model for optimal utilization of agricultural resources. The results prove that the proposed model enhances the economic benefit by minimizing water requirements and also enhances the yield of the crops for economic development.

Data Availability

The data used are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this study.

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