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Research on Optimization of Rural Characteristic Industry Development Path Based on Multi-Objective Planning in the Context of Rural Revitalization

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ABSTRACT

Encouraged by the strategy of rural revitalization, rural areas in many places are exploring the development path of characteristic industries. The article embeds the multi-objective optimization model into the development of rural characteristic industries to optimize the current rural industrial development path. The multi-objective optimization model of rural characteristic industry development is constructed, and the ACO-PSO algorithm is used to solve the model, in order to realize the organic unity of economic, social and ecological benefits of rural industry development. The multi-objective optimization model is used to optimize the industrial development of village S. The total regional output value of village S in 2035 is 2.08 times of that in 2025. The proportion of output value of primary industry and secondary industry decreases by 20.29% and 18.50% respectively. The proportion of tertiary industry output value increases by 38.79%, and the industrial structure becomes more and more reasonable. After the multi-objective optimization, Village S changes the development mode at the expense of resources and the environment, and maintains the survival of the ecological environment by appropriately slowing down the economic development. After the multi-objective optimization, the total output value of the primary industry and the per capita income of farmers in Village S increased by 17,412 and 205.76 yuan respectively. The total output of tourism in the tertiary industry is 465,222,000 yuan, which is 126% higher than that before optimization.

Keywords: multi-objective optimization; ACO-PSO algorithm; industrial structure; development path optimization

1. Introduction

Rural revitalization is an important strategy to realize the comprehensive construction of a strong socialist modernization country, and in the process of rural revitalization, the development of rural

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characteristic industries plays a key role. The core of rural revitalization is to optimize the industrial structure according to the local resource endowment and market demand, so as to realize the high-quality development of rural economy [1-3]. First of all, we should pay attention to the technology and precision of agricultural production. Rural areas should increase the research and development and promotion of modern agricultural technology to improve agricultural efficiency and yield level. Secondly, rural specialty industries should be developed. By cultivating and promoting agricultural products with local characteristics and competitiveness, we can realize farmers' income increase and effective use of land resources [4-7].

Good infrastructure is the basic condition for rural revitalization and the development of rural characteristic industries. First of all, it is necessary to improve the rural transportation network. Poor rural transportation is a major bottleneck in rural revitalization. The government should increase the construction and renovation of rural roads to improve the convenience of farmers' travel [8-11]. Secondly, the construction of rural water supply and electricity should be strengthened. It is an important link to promote the development of rural specialty industries to guarantee the water and electricity resources needed for farmers' living needs and agricultural production [12-14]. Market-oriented operation is an important way for the development of rural characteristic industries. The government should formulate supportive policies to guide farmers to carry out market-oriented business activities. On the one hand, farmers should be incentivized to improve the competitiveness of agricultural products in the market through moderate scale operation and rural cooperatives, etc. On the other hand, it is necessary to enhance the competitiveness of agricultural products in the market. On the other hand, it is necessary to strengthen the brand building and marketing channel development of agricultural products to improve the added value and market share of products [15-18]. In addition, playing the main role of farmers, strengthening rural financial support, and strengthening scientific and technological innovation are all important ways for the development of rural specialty industries [19-20].

Literature [21] explored the theoretical basis and logical mechanism of high-quality development of rural revitalization in the old revolutionary area of Ganzhou, and constructed a high-quality development measurement system. The study points out that the overall level of high-quality development of rural revitalization in the area is uneven. It also proposes strategies such as vigorously developing the rural real economy in order to create a path optimization for rural revitalization high-quality development. Literature [22] aims to empirically study the impact of rural finance on the integration of rural primary, secondary and tertiary industries. Based on relevant data, the impact of rural finance on rural industrial integration was estimated using Logit and Probit regression models. The results of the study show that rural finance has a positive effect on promoting farmers' participation in new agricultural business organizations and provides policy recommendations for promoting rural industrial integration. Literature [23] constructed a rural development evaluation model for rural revitalization strategy. Taking Pinggu District as an example, the development model and regional characteristics of the vernacular villages are elaborated, with a view to providing guidance for rural development planning under the rural revitalization strategy. The research results are also discussed in detail. Literature [24] constructed an evaluation model based on gray rough set theory and TOPSIS ideal solution similarity ranking preference technique. And by establishing the evaluation index system of the development level of characteristic towns and evaluating the development level by using TOPSIS model, the study verifies the validity and feasibility of the proposed model. Literature [25] took Xi'an metropolitan area as an example, and used methods such as kernel density analysis to specify the spatial differentiation law of rural characteristic industries. It also proposes a three-dimensional development strategy of “industry-space-institution” for the development of rural specialty industries in order to provide a reference for the development of rural specialty industries in the metropolitan area. Literature [26] emphasizes the importance of industrialized management in realizing the sustainable development of agriculture and rural economy.

It also reveals the problems in the industrialized operation of characteristic agricultural products in underdeveloped areas and puts forward specific development paths in combination with practical experience. Literature [27] shows the importance of digitalization to achieve rural industrial revitalization. It also discusses the synergistic mechanism of multiple factors for rural industry revitalization from the dimensions of technology and environment. The mechanism was investigated using a combination of necessary condition analysis and fuzzy set qualitative comparative analysis. The results indicate that there are no necessary conditions for achieving high-level rural industrial revitalization.

In this paper, on the basis of preliminary research on rural characteristic industries, for the purpose of maximizing economic production benefits, social life benefits and ecological resource benefits, the economic indicators in primary, secondary and tertiary industries are screened, which are taken as the decision variables of the multi-objective optimization model, and after generating the objective function, the multi-objective coordinated development optimization model of rural characteristic industries is constructed based on the examination of constraint conditions. Ant colony and particle swarm combination algorithm are combined as the solution method of multi-objective optimization model. Village S is selected for the multi-objective optimization experiment, and the multi-objective optimization model is used to optimize the industrial structure, the pollution emission situation of the secondary industry, and the development of the primary and tertiary industries in the village.

2. Optimization model construction of multi-objective coordinated development of rural characteristic industries

2.1. *Specialized rural industries*

Rural characteristic industry refers to the characteristic breeding, processing, food and handicraft industries that have distinctive features and unique advantages in rural areas or agricultural resource environment, and can form a certain scale and high added value. The formation and development of rural characteristic industries cannot be separated from the support and baking of agricultural and rural regional characteristics, history and culture, natural resources and other factors. It creates characteristic products and services, enhances the level of regional economic development and increases the income of residents by tapping and utilizing the unique resources, technologies, brands and other elements of rural areas or agriculture, and also has strong demonstration and radiation effects, which is of great significance in promoting the comprehensive revitalization of the countryside. Rural characteristic industries have the following characteristics, firstly, they embody regional differences and advantages, and are an important part of the local economy. Secondly, they have distinctive features and unique competitive advantages in products or services, and can meet the special needs of consumers. Thirdly, they are mainly characterized by a small and refined development mode, focusing on quality and innovation, and are able to provide high value-added products and services, which helps to enhance regional economic efficiency and competitiveness. In addition, rural specialty industries are able to promote the development of related industrial chains, leading to increased employment and farmers' incomes, and promoting the prosperity and stability of the rural economy.

2.2. *Multi-objective optimization model*

The idea of multi-objective optimization first appeared in 1776 in the utility theory of economics. Multi-objective optimization problems are widely found in the disciplines of economics, cybernetics and systems engineering [28-29].

Multi-objective optimization problems are a more common class of optimization problems in research fields and real projects. In the multi-objective optimization of a project, the needs of each sub-objective need to be considered comprehensively. However, in practice, the sub-objectives are usually constrained by each other, contradict each other, and it is difficult to achieve the optimization at the same time. Therefore, in multi-objective optimization, the weight of the sub-objectives in the overall objective and the optimization of each sub-objective should be considered simultaneously, so as to achieve the overall optimization of the overall objective. Since all the sub-objectives need to be considered at the same time, the optimization method is difficult. Considering that the traditional optimization method requires strict form of evaluation function, how to deal with this type of problem mathematically is a key issue. When solving the multi-objective optimization problem, the original problem can be transformed into a specific mathematical model by certain methods. The mathematical functions are used to quantify the sub-objectives, and all the functions are integrated into a unified mathematical model according to the optimization requirements and constraints. By this method, all multi-objective optimization problems can theoretically be transformed into mathematical models expressed in functional form. The general multi-objective optimization model is shown in the following equation:

$$\begin{aligned} &\min(x) = f_1(x), f_2(x), \ldots, f_n(x), x \in \Omega \\ &x \in \Omega \subset Z^m \\ &S.t.\ h(x) \geq 0, i = 1, 2, \ldots, q \end{aligned} \tag{1}$$

where $x = (x_1, x_2, \ldots, x_m)^T$ is a m-dimensional vector in Z^m space representing a set of feasible solutions. $f_i(x)(i = 1, 2, \ldots, n)$ is a mathematical function that quantifies and evaluates each sub-optimization objective, which have inconsistent trends, i.e., there is no $\exists x \in \Omega$ such that $f_1(x), f_2(x), \ldots, f_m(x)$ achieves the optimal value at x at the same time. The space where the n-dimensional vector $(f_1(x), f_2(x), \ldots, f_n(x))$ is located is the objective space consisting of the sub-objective functions. $h_i(x) \geq 0$, $i = 1, 2, \ldots, q$ is the constraints of the original problem.

2.3. Modeling

2.3.1. Decision-making variables. The decision variables in this paper consist of the total output value of primary, secondary and tertiary industry projects. Among them, the primary industry is agriculture, forestry, animal husbandry and fishery. The secondary industry is industry and so on. The tertiary industry consists of transportation and postal services, wholesale and retail trade, accommodation and catering, tourism and leisure. The set of decision variables is shown in equation (2):

$$X = \left\{ X_{ij} \right\} \tag{2}$$

where X_{ij} denotes the j rd decision variable for industry i.

2.3.2. Objective function. The goal of industrial structure optimization is to maximize the benefits of economic production, social life and ecological resources.

1) Economic production efficiency target. The objective of economic production efficiency selects three indicators of regional gross product, social fixed asset investment and fiscal revenue as the objective of economic production efficiency. The economic production efficiency target is to obtain the maximum weighted sum of gross product, social fixed asset investment and fiscal revenue per unit of output value of each sector. The calculation formula is shown in equation (3):

$$\max f_1 = w_1 \sum_{i=1}^{3} \sum_{j=1}^{n_i} \left\{ \left[\sum_{t_0}^{N} \frac{A_{ij}^{(t)}}{Z_{ij}^{(t)}} / T \right] X_{ij} \right\}$$
$$+ w_2 \sum_{i=1}^{3} \sum_{j=1}^{n_i} \left\{ \left[\sum_{t_0}^{N} \frac{B_{ij}^{(t)}}{Z_{ij}^{(t)}} / T \right] X_{ij} \right\} \tag{3}$$
$$+ w_3 \sum_{i=1}^{3} \sum_{j=1}^{n_i} \left\{ \left[\sum_{t_0}^{N} \frac{C_{ij}^{(t)}}{Z_{ij}^{(t)}} / T \right] X_{ij} \right\}$$

Where $A_{ij}^{(t)}$ is the gross regional product of the j rd decision variable of the i nd industry in the t th year, $B_{ij}^{(t)}$ is the fixed asset investment of the j th decision variable of the i th industry in the t th year, $C_{ij}^{(t)}$ is the local fiscal revenue of the j th decision variable of the i th industry in the t th year, $Z_{ij}^{(t)}$ is the total output value of the j th decision variable of the i th industry in the t th year, and t is the year of calculation.

2) Objective of Social Life Benefits. The social life benefits studied in this paper are mainly considered from the perspective of residents' income. Therefore, the maximization of the cumulative value of employment growth rate, total wage growth rate and average wage growth rate can be regarded as the second objective, as shown in Equation (4):

$$\max f_2 = w_4 \sum_{i=1}^{3} \sum_{j=1}^{n_i} \left\{ \left[\sum_{t_0}^{N} \frac{D_{ij}^{(t)}}{Z_{ij}^{(t)}} / T \right] X_{ij} \right\}$$
$$+ w_s \sum_{i=1}^{3} \sum_{j=1}^{n_i} \left\{ \left[\sum_{t_0}^{N} \frac{E_{ij}^{(t)}}{Z_{ij}^{(t)}} / T \right] X_{ij} \right\} \tag{4}$$
$$+ w_6 \sum_{i=1}^{3} \sum_{j=1}^{n_i} \left\{ \left[\sum_{t_0}^{N} \frac{M_{ij}^{(t)}}{Z_{ij}^{(t)}} / T \right] X_{ij} \right\}$$

Where $D_{ij}^{(t)}$ indicates the employment growth rate of the j th decision variable of the i rd industry in the t nd year, $E_{ij}^{(t)}$ indicates the per capita wage growth rate of the j th decision variable of the i th industry in the t th year, and $M_{ij}^{(t)}$ indicates the growth rate of the total wage of the j th decision variable of the i th industry in the t th year.

3) Ecological Resource Efficiency Objective. The eco-efficiency resource objective mainly considers two aspects of resource conservation and environmental protection. That is, minimizing energy use and pollution emission is the third objective of the model. Specifically, it is to minimize solid, liquid and gaseous pollutant emissions and energy utilization of coal, oil and natural gas in each industrial sector, as shown in equation (5):

$$\begin{aligned}\min f_3 = & w_7 \sum_{i=1}^{3}\sum_{j=1}^{n_i}\left\{\left[\sum_{t_0}^{N}\frac{F_{ij}^{(t)}}{Z_{ij}^{(t)}}/T\right]X_{ij}\right\} \\ & + w_8 \sum_{i=1}^{3}\sum_{j=1}^{n_i}\left\{\left[\sum_{t_0}^{N}\frac{P_{ij}^{(t)}}{Z_{ij}^{(t)}}/T\right]X_{ij}\right\} \\ & + w_9 \sum_{i=1}^{3}\sum_{j=1}^{n_i}\left\{\left[\sum_{t_0}^{N}\frac{Q_{ij}^{(t)}}{Z_{ij}^{(t)}}/T\right]X_{ij}\right\} \\ & + w_{10} \sum_{i=1}^{3}\sum_{j=1}^{n_i}\left\{\left[\sum_{t_0}^{N}\frac{O_{ij}^{(t)}}{Z_{ij}^{(t)}}/T\right]X_{ij}\right\} \\ & + w_{11} \sum_{i=1}^{3}\sum_{j=1}^{n_i}\left\{\left[\sum_{t_0}^{N}\frac{H_{ij}^{(t)}}{Z_{ij}^{(t)}}/T\right]X_{ij}\right\} \\ & + w_{12} \sum_{i=1}^{3}\sum_{j=1}^{n_i}\left\{\left[\sum_{t_0}^{N}\frac{U_{ij}^{(t)}}{Z_{ij}^{(t)}}/T\right]X_{ij}\right\}\end{aligned} \tag{5}$$

Among them, $F_{ij}^{(t)}$ represents the solid pollutant emissions of the j rd decision variable of the i industry in the tth year, $P_{ij}^{(t)}$ represents the liquid pollutant emissions of the j th decision variable of the ith industry in the tth year, $Q_{ij}^{(t)}$ represents the gas pollutant emissions of the j th decision variable of the tth and ith industries, $O_{ij}^{(t)}$ represents the oil consumption of the j th decision variable of the ith industry in the tth year, and $H_{ij}^{(t)}$ represents the coal consumption of the j th decision variable of the ith industry in the tth year. $U_{ij}^{(t)}$ represents the gas consumption for the i rd industry and the j th decision variable in the tnd year.

2.3.3. Constraints:

1) Resource constraints:

(1) Energy consumption constraint: energy has always been an important resource for economic development. Effective optimization of industrial structure can save energy. Therefore, the rationality of energy utilization needs to be considered in the process of industrial structure optimization. In order to maintain economic security, the total energy consumption of each industrial sector is less than the total available energy. See equation (6):

$$\sum_{i=1}^{3}\sum_{j=1}^{n_i}\left\{\left[\left(\sum_{t_o}^{N}\frac{G_{ij}^{(t)}}{Z_{ij}^{(t)}}\right)/T\right]X_{ij}\right\} \le R \tag{6}$$

Where, $G_{ij}^{(t)}$ denotes the energy consumption of the ird industry jth decision variable in year t. R_1 is the maximum available amount of energy.

(2) Industry production capacity constraint: in order to maintain the stability of the economic system and the availability of resources, sectoral production capacity should be considered in the process of industrial reconstruction. That is, the total output value of each industry each year cannot be higher than the upper limit of the growth rate of each industry, nor lower than the lower limit of the growth rate of the total output value of the industry. See equation (7):

$$\alpha_{ij} Z_{ij}^{(N)} < X_{ij} < \beta_{ij} Z_{ij}^{(N)} \tag{7}$$

Where $\alpha_{ij} < 1 < \beta_{ij}$, α_{ij} and β_{ij} are the lower and upper limits of the output growth rate of each industry respectively.

2) Ecological environment constraints. The ecological environment constraint is mainly to control the emission of pollutants, including solid pollutants, liquid pollutants and gas pollutants.

(1) Solid pollutant constraints: the total solid pollutant emissions of each industrial sector are less than the permitted emissions. See equation (8) shown:

$$\sum_{i=1}^{3}\sum_{j=1}^{n_i}\left\{\left[\left(\sum_{t_o}^{N}\frac{F_{ij}^{(t)}}{Z_{ij}^{(t)}}\right)/T\right]X_{ij}\right\}\leq S_1 \tag{8}$$

where S_1 indicates the maximum emission limit for solid pollutants in the base year.

(2) Liquid pollutant limitations: the total liquid pollutant emissions from each industrial sector are less than the allowable emissions. See equation (9) shown:

$$\sum_{i=1}^{3}\sum_{j=1}^{n_i}\left\{\left[\left(\sum_{t_o}^{N}\frac{P_{ij}^{(t)}}{Z_{ij}^{(t)}}\right)/T\right]X_{ij}\right\}\leq S_2 \tag{9}$$

where S_2 indicates the maximum emission limit for liquid pollutants in the base year.

(3) Limitation of gaseous pollutants: the total emissions of gaseous pollutants from each industrial sector are less than the permitted emissions. See equation (10) shown:

$$\sum_{i=1}^{3}\sum_{j=1}^{n_i}\left\{\left[\left(\sum_{t_0}^{N}\frac{Q_{ij}^{(t)}}{Z_{ij}^{(t)}}\right)/T\right]X_{ij}\right\}\leq S_3 \tag{10}$$

where S_3 represents the constrained maximum emissions of liquid pollutants in the base year.

3) Labor force constraint. The labor force constraint refers to the total amount of labor used in each industry sector that is less than the number of employable people in the area. See equation (11):

$$\sum_{i=1}^{3}\sum_{j=1}^{n_i}\left\{\left[\left(\sum_{t_o}^{N}\frac{D_{ij}^{(t)}}{Z_{ij}^{(t)}}\right)/T\right]X_{ij}\right\}\leq K \tag{11}$$

where K represents the number of regionally employable people.

4) Non-negative constraints. The non-negative constraint is applied to the independent variables in the model. See equation (12):

$$X_{ij}\geq 0\forall i,j \tag{12}$$

2.4. Model solving

In this paper, the Ant Colony and Particle Swarm Combined Algorithm (ACO-PSO) is applied to the solution of a multi-objective optimization model [30]. The basic idea is that in the first stage of the combined ACO-PSO algorithm, the quality performance of the PSO algorithm for fast convergence is utilized for the initial search and repeated iterations are performed to obtain the suboptimal solution of the model, and a number of suboptimal solutions are output, which are then converted to the encoding. In the second stage, the suboptimal solutions output in the first stage are used to optimize the initial state of the pheromone in the ACO algorithm, and then the traditional ACO algorithm process is followed to finally output a number of suboptimal solutions.

3. Results of the optimization of the development path of rural characteristic industries

This paper takes S village as the object of this multi-objective optimization experiment of rural characteristic industry development, through the analysis of the data and situation of the past characteristic industry development in S village, through the optimization of the multi-objective coordinated development optimization model constructed in this paper, and examines the optimization results of the industrial structure, the situation of the pollution emission, and the primary, secondary and tertiary industries in S village.

In 2024, the total industrial income of village S is 1,359,600 yuan, of which the income of primary industry is 608,800 yuan, accounting for 44.78% of the total income of the village, which mainly includes the characteristic industries such as green organic agriculture, flowers and seedlings, etc. The income of secondary industry of village S is 560,700 yuan, accounting for 41.24% of the total income of the village, which is mainly for the characteristic industries represented by the characteristic agricultural products processing, characteristic textile industry, etc. The income of tertiary industry of village S is 190,100 yuan, accounting for 41.24% of the total income of the village. s village tertiary industry income 190,100 yuan, accounting for 13.98% of the village's total income, mainly including rural characteristics of eco-tourism, rural e-commerce and other specialty industries.

3.1. Industrial structure

Substituting all known data into the multi-objective optimization model and predicting the unknown data, the optimization results of the industrial structure of S village from 2025 to 2035 are given as shown in Table 1.

Analyzing the optimization results in Table 1, it can be seen very simply that, after optimization, the total regional output value of S village can reach 3,054,500,000 yuan in 2035, which is 2.08 times of that of 2025, which is basically in line with the goal of doubling the output value of S village planned to be achieved by using ten years' time. The proportion of output value of primary industry gradually decreases after optimization, from 41.18% in 2025 to 20.89% in 2035, and the proportion of output value of primary industry decreases by a large margin. The proportion of output value of secondary industry decreases by a larger extent, and the proportion of output value of secondary industry decreases by 18.50% from 2025 to 2035. The proportion of output value of the tertiary industry gradually increases, that is, the means of production and labor force gradually transfer from the primary and secondary industries to the tertiary industry, which is in line with the trend of rationalization and advancement of industrial structure. By 2035, the proportion of output value of tertiary industry can reach 55.30%, but there is still much room for improvement, which shows that the optimization of industrial structure is a long-term and complex systematic project, and requires unremitting efforts to realize the advanced process.

Table 1. Results of industrial structure optimization

Year	Gross output (104 yuan)	Proportion of first industry (%)	Proportion of secondary industry (%)	Proportion of tertiary industry (%)
2025	154.31	41.18	42.31	16.51
2026	168.67	38.44	41.23	20.33
2027	176.50	34.71	36.97	28.32
2028	180.37	30.81	32.49	36.70
2029	192.29	28.27	29.99	41.74
2030	209.82	27.92	28.20	43.88
2031	216.99	26.37	27.77	45.86
2032	229.45	24.28	25.57	50.15
2033	255.17	23.79	24.89	51.32
2034	288.23	12.76	24.38	62.86
2035	320.45	20.89	23.81	55.30

3.2. Optimization of pollution emissions from the secondary sector

This subsection explores the optimization results of pollution emissions from the secondary industry (industry) in Village S. After multi-objective optimization, the total amount of energy consumption, water consumption, wastewater emissions, sulfur dioxide emissions, soot emissions, nitrogen oxide emissions, industrial solid waste emissions from the secondary industry in Village S from 2025 to 2035, and the total amount of energy consumption per unit of GDP, water consumption, wastewater emissions, sulfur dioxide emissions, soot emissions, nitrogen oxide emissions, industrial solid waste emissions are shown in Table 2 and Table 3, where A, B, C, D, E, F, G represent energy consumption, water consumption, wastewater emissions, sulfur dioxide emissions, soot emissions, nitrogen oxide emissions, industrial solid waste emissions, respectively.

Analyzing Table 2, after the optimization of industrial structure, the total amount of energy consumption, water consumption and various pollutant emissions still have different magnitudes of increase, this is because the calculated energy consumption and pollutant emission results are obtained under the assumption of constant technical conditions and other levels, that is, assuming that the energy consumption coefficient and pollutant emission coefficient are kept at the level of the base year, so that with the development of the economy, the total amount of energy consumption and the total amount of pollutant emissions have increased. Therefore, with the economic development, the total energy consumption and pollutant emission have increased. According to the statistics of past years, with the improvement of technology and management level, the coefficient of energy emission and the coefficient of pollutant emission are gradually decreasing. Therefore, if we consider the factors of technology and carry out the optimization of industrial structure, so as to make the resources more reasonably distributed among industries and inhibit the development of high-energy-consuming and high-polluting industries, we can surely realize the decrease of total energy consumption and pollutant emission.

Analyzing Table 3, after the optimization, the energy consumption, water consumption and various pollutant emissions per unit of GDP have decreased to different degrees, which indicates that the growth of total energy consumption, water consumption and pollutant emissions is smaller than the growth of GDP, i.e., the resources have been more reasonably utilized, and high energy-consuming and high-polluting industries have also been effectively suppressed.

Table 2. Energy consumption and pollutant emission amounts of per GDP after optimization

Year	A/104 tons	B/104 tons	C/ton	D/ton	E/ton	F/ton	G/104 ton
2025	58.59	5244.63	427.88	0.398	0.0323	0.1598	11.28
2026	63.09	5270.54	425.48	0.397	0.0321	0.1547	11.27
2027	65.53	5551.32	420.54	0.394	0.0319	0.1519	11.20
2028	68.52	5591.58	416.41	0.398	0.0321	0.1534	11.62
2029	70.07	5669.10	415.69	0.403	0.0326	0.1567	11.84
2030	75.16	5686.26	412.54	0.409	0.0332	0.1622	12.03
2031	81.57	5806.70	411.68	0.415	0.0337	0.1694	12.45
2032	83.68	5861.27	408.05	0.421	0.0342	0.1748	12.95
2033	85.97	5918.91	407.89	0.424	0.0356	0.1802	13.52
2034	88.92	5926.74	406.08	0.427	0.0359	0.1896	14.06
2035	89.44	6106.03	402.06	0.432	0.0364	0.1964	15.37

Table 3. Energy consumption and pollutant emission coefficients of per GDP after optimization

Year	A coefficient (104 yuan/ton)	B coefficient (100 yuan/ton)	C coefficient (104 yuan/ton)	D coefficient (107 yuan/ton)	E coefficient (108 yuan/ton)	F coefficient (107 yuan/ton)	G coefficient (104 yuan/ton)
2025	0.3405	0.3585	2.1029	0.1873	0.1483	0.0497	0.0576
2026	0.3372	0.333	2.0886	0.1649	0.1468	0.0495	0.0542
2027	0.2892	0.307	2.0675	0.1534	0.1453	0.0494	0.0503
2028	0.2677	0.2748	1.9243	0.1476	0.1377	0.049	0.0454
2029	0.2587	0.2501	1.8261	0.1452	0.1254	0.0466	0.0417
2030	0.2462	0.2302	1.7527	0.1414	0.1193	0.0444	0.0399
2031	0.2216	0.2213	1.6831	0.1349	0.1109	0.0442	0.0377
2032	0.2152	0.205	1.4331	0.1198	0.1037	0.0388	0.0355
2033	0.2069	0.2026	1.3856	0.1178	0.0914	0.0375	0.0317
2034	0.2037	0.1999	1.1111	0.1038	0.0893	0.0328	0.0308
2035	0.1898	0.1859	0.9892	0.0918	0.0785	0.0302	0.0273

After the optimization of industrial structure, the GDP growth rate of Village S from 2025 to 2035 is 9.31%, 4.64%, 2.19%, 6.61%, 9.12%, 3.42%, 5.74%, 11.21%, 12.96%, and 11.18%, respectively. And according to the statistics, the GDP growth rate of Village S from 2017 to 2024 is 10.26%, 14.57%, 15.66%, 17.53%, 15.38%, 13.18%, and 12.49%, respectively. This on the one hand explains the rapid economic development of S village in recent years, compared with the results of industrial structure optimization, and points out that this development is actually at the expense of resources and the environment in exchange for an unscientific and unsustainable way of development. If the economy develops in this way, it is impossible to maintain such a high growth rate. It can be seen that by 2023 and 2024, the GDP growth rate has already declined. After the optimization of the industrial structure, the speed of economic development has been temporarily reduced, so that resources can be reorganized in a more reasonable way, and after eight years of adjustment, the GDP growth rate can be increased to about 10% by 2033, and in the future, under a more reasonable industrial structure, the GDP can maintain rapid growth without sacrificing resources and the environment, which is a sustainable way of development.

3.3. Primary and tertiary sector optimization results

This subsection uses the multi-objective optimization model to optimize the primary and tertiary industries in S village, and compares the optimization results with the level of the benchmark industry before optimization, so as to provide a reference for S village to adjust the development path of the primary and tertiary industries.

3.3.1. Primary sector. The economic indicators in the primary industry (planting, animal husbandry, fishery and forestry) of village S were screened and entered into the multi-objective optimization model as decision variables, and the decision variables of the primary industry (agriculture) are shown in Table 4.

Table 4. Decision-making variable of agricultural industries

Industry		Decision-making
Planting	Grain crop (X1)	Rice (X11)
		Wheat (X12)
		Corn (X13)
		Soybean (X14)
		Potato sort (X15)
	Economic crop (X2)	Cotton (X21)
		Oil crop (X22)
		Tobacco leaf (X23)
		Medicinal materials (X24)
		Vegetables (X25)
	Feed (X3)	Clover (X31)
		Feed corn (X32)
Stockbreeding	Food-saving type (X4)	Milk (X41)
		Beef (X42)
		Mutton (X43)
	Food-consuming type (X5)	Pork (X51)
		Egg (X52)
		Poultry (X53)
Fishery	Fishery (X6)	Aquaculture area (X61)
Forestry	Forestry (X7)	Woodland area (X71)

Entering the above decision variables into the model, the optimized main economic indicators are obtained as shown in Table 5, and the optimization results of the primary industry are shown in Table 6, in which the indicator units of plantation, fishery and forestry are all hectares, and the indicator unit of animal husbandry is tons. As can be seen from Table 5 and Table 6, the optimized downward adjustment of the area and output of plantation, animal husbandry, fishery and forestry in the primary industry of Village S did not have too much impact on the output value and per capita income of the farmers, but rather increased the output value and the income of the farmers to a certain extent, which was mainly due to the high price of agricultural products in the market.

Table 5. Optimized main economic index

Index	2024	Optimization	Index	2024	Optimization
Rice (X11)	225.10	195.62	Clover (X31)	25.15	21.32
Wheat (X12)	120.35	95.68	Feed corn (X32)	8.53	10.56
Corn (X13)	28.45	50.36	Milk (X41)	32.47	11.68
Soybean (X14)	4.36	8.48	Beef (X42)	26.34	15.24
Potato sort (X15)	17.26	24.63	Mutton (X43)	20.32	6.23
Cotton (X21)	45.68	45.04	Pork (X51)	300.55	281.52
Oil crop (X22)	160.43	140.36	Egg (X52)	50.72	40.33
Tobacco leaf (X23)	10.71	5.23	Poultry (X53)	142.39	88.73
Medicinal materials (X24)	2.32	1.05	Aquaculture area (X61)	100.29	60.37
Vegetables (X25)	150.66	95.42	Woodland area (X71)	194.06	250.31

Table 6. Optimization results of the first industry

	2024	Optimization
Grain crop area (hm^2)	395.52	374.77
Economic crop area (hm^2)	369.80	287.10
Grain crop yield (ton)	2598.44	2348.65
Economic crop yield (ton)	521.47	649.45
Planting output yuan)	271154	253482
Stockbreeding yield (ton)	572.79	443.73
Stockbreeding output (yuan)	91541	84555
Fishery output (yuan)	64784	106854
Total output (yuan)	427479	444891
Per capita income of farmers	5051.54	5257.30

3.3.2. Tertiary sector. In recent years, rural tourism has developed rapidly. This paper takes tourism as an example of the tertiary industry to explore the optimization results of the tertiary industry in village S. The simulation results of the multi-objective optimization model of tourism industry structure in village S are shown in Table 7.

Observing Table 7, it can be seen that the total output of tourism industry in Village S after optimization achieves a growth of 126%, and the number of tourism employment increases from 186 people before optimization to 324 people, which achieves an employment growth of 74%, and opens up a new direction for the employment of villagers in Village S, while realizing the transformation and upgrading of the industry and the increase of production capacity. In addition, as can be seen from Table 7, after the optimization of the multi-objective planning model, the proportion of basic-level industries in the tourism industry of Village S decreased while the proportion of high-level industries increased by 10.12%, which has long-term benefits for the sustainable development of the tourism industry in Village S.

Table 7. The multi-objective optimization results of tourism industry

	2024	Optimization
Tourism total output (10^4 yuan)	20.565	46.522
Transportation proportion (%)	20.65	19.92
Accommodation proportion (%)	16.08	14.31
Catering proportion (%)	13.84	10.55
Postal service proportion (%)	3.05	0.62
Other tourism industry proportion (%)	2.92	1.02
The total proportion of basic industry (%)	56.54	46.42
Shopping proportion (%)	35.24	40.54
Sightseeing proportion (%)	6.18	9.84
Entertainment industry proportion (%)	2.04	3.20
The total proportion of advanced industry (%)	43.46	53.58
Tourism total output growth rate (%)	-	1.26
Tourist industry employment (person)	186	324
Energy consumption (J)	5.684	5.512
CO_2 emission (ton)	7.948	7.054

3.4. Optimization path of characteristic industries in S village

As can be seen from the previous section, the industrial development level of S village has been improved after its industrial adjustment through the multi-objective optimization model. Based on the unique industries of S village, such as green organic agriculture, specialty textile industry, eco-tourism and rural e-commerce industry, after comprehensive consideration, the following suggestions are made for the unique industries of S village:

1) Due to people's emphasis on food safety and expanding demand for ornamental plants, the market demand for green and organic agriculture and flower and seedling industries in the primary industry of Village S is increasing, and Village S should appropriately adjust the production proportion of agriculture, forestry, animal husbandry and fishery in the primary industry, focusing on the production of green and organic vegetables and flower and seedling trees in the plantation industry.

2) The specialty industries with high output value in the primary industry of Village S are mainly based on agricultural products processing and textile industry, which are mainly dependent on the production of the primary industry. Therefore, while focusing on the development of green organic agriculture and flowers and seedlings, Village S should ensure the production of major agricultural products and cash crops such as cotton, so as to provide sufficient means of production for the secondary industry.

3) In recent years, rural ecotourism has become a new form of tourism and one of the ways for urban people to relax and return to nature. Village S can take advantage of the situation to promote local rural tourism, while improving the local tourism infrastructure. It can also continue to vigorously develop the rural e-commerce industry through the Internet, broadening sales channels and expanding sales markets for products in the primary and secondary industries while driving local employment.

4. Conclusion

The article constructs a multi-objective coordinated development optimization model for rural characteristic industries by analyzing rural characteristic industries, screening decision variables, generating the objective function of multi-objective optimization, and comprehensively considering the constraints. The empirical study of S village is used to explore the optimization results of the multi-objective optimization model on rural characteristic industries.

1) The total regional output value of Village S in 2035 is 2.08 times of that in 2025. The proportion of output value of primary industry and secondary industry gradually decreases after optimization, respectively by 20.29% and 18.50%. The proportion of output value of the tertiary industry increases by 38.79%, and the tertiary industry gets more development inclination, which is in line with the logic of industrial upgrading.The proportion of output value of the tertiary industry is 55.30% in 2035, which still needs to carry out industrial optimization.

2) The GDP growth rate of Village S from 2025 to 2035 is 9.31%, 4.64%, 2.19%, 6.61%, 9.12%, 3.42%, 5.74%, 11.21%, 12.96%, and 11.18%, respectively, and according to the statistical data, the GDP growth rate of Village S from 2017 to 2024 is more than 10%, which indicates that Village S in recent years has had economic development at the expense of resources and environment is not a long-term solution. After the optimization of industrial structure, the rate of economic development decreases until 2033 when the GDP growth rate increases to about 10% to maintain the sustainability of industrial development.

3) The primary industry in Village S achieves an increase in the total output value of the primary industry and the per capita income of the farmers after the multi-objective optimization, which increases by 17,412 and 205.76 Yuan respectively. The tourism industry in the tertiary industry, on the other hand, realized an increase of 126%, with a total output of 465.22 million yuan.

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