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The Sustainable Rural Industrial Development under Entrepreneurship and Deep Learning from Digital Empowerment

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Abstract: This paper aims to realize the planning of resource utilization and development of rural industries endowed by digitalization under entrepreneurship. First, the global classic practical experience of digitizing rural industries is studied, and the development model of existing rural industries is captured from the perspective of entrepreneurship. Second, the influencing factors of rural industrial development are extracted, the structure of resource development is analyzed, and a Neural Network (NN) model of industrial development aiming at expected per capita annual income is established. In addition, a Genetic Algorithm (GA) is introduced to learn the weights of influencing factors in the model. The structure of the NN is determined through extensive experiments. Finally, conclusions are drawn through the simulation and experiment of NN and GA. Tourism, infrastructure, and transportation planning have weights of 7.79, 5.6, and 6.4, respectively, and these three sectors should be vigorously developed. In the future, the weight values of these factors can be used for reference, and the development of various aspects can be refined. This paper clarifies the core of industrial development in rural revitalization based on the perspective of entrepreneurship. The problem of how to realize the optimal utilization of resources is solved scientifically and rationally through the mathematical model. The introduction of deep learning algorithm models provides data support for resource allocation and industrial planning in the process of digital empowerment of traditional rural industries, which is of great value and significance for exploring digital models for rural industry development.

Keywords: entrepreneurship; sustainable development; deep learning; neural network; industrial planning; digital development

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1. Introduction

Digital rural is an important application in the economic and social development of agriculture and rural areas. With the improvement of farmers' modern information skills, digital villages reflect the modernization and transformation processes of agriculture and rural areas. The promotion of digital rural construction not only has positive significance for rural revitalization and digital China construction but also has an important impact on the high quality of the rural economy and sustainable rural development [1]. At present, China's active development of a digital economy and construction of digital countryside is the opening up of a new direction of China's rural revitalization and the improvement of China's agricultural modernization development. Based on this background, this paper researches digital development in rural areas. Agriculture has always been a key area of economic and social development, which is related to overall development, mutual support, and social stability. The urbanization process has accelerated, the population has concentrated in county towns, and the level of rural development has been low for a long time. Income growth is slow, rural environmental governance is weak, rural development is difficult, and new development models and paths are urgently needed. The current urban planning and construction and land resource supply are incompatible with the rapid growth of the total population [2]. Meanwhile, the carrying capacity of urban planning resources has also been challenged. Infrastructure lags seriously behind the needs of economic and social development. Spending on education and health care housing is too high, and urban capital has nowhere to flow. These problems have brought severe challenges to the healthy development of cities. Cities need new vast spaces and models to develop. Rural planning and construction under digitalization can alleviate this problem and are also significant for urbanization. Private enterprises are very important for rural construction planning. Entrepreneurs are important subjects of economic activities and have made outstanding contributions to increasing jobs, accumulating social wealth, promoting economic and social development, and enhancing national strength [3]. This paper will study the digital empowerment of rural industries from the perspective of entrepreneurship.

Kartiasih et al. (2022) showed that digital rural areas were networked, informatized, and digitalized. The information dividend and online development opportunities brought by the construction of digital rural areas significantly impacted rural residents' participation in e-commerce. It helped to increase the disposable income of rural residents, changed the consumption concept, consumption mode, and consumption structure of rural residents, released the vitality of rural residents' online consumption, and promoted the upgrading of rural residents' consumption structure [4]. Merrell (2022) proposed that from the perspective of technical governance, the construction of digital villages brought about the improvement of rural residents' information quality, the optimization of government organization and management services, and the improvement of policy design and management systems. Thus, the countryside became a community of interests, which made up for the digital divide between urban and rural areas [5]. Chen et al. (2022) found that the development of digital finance could not only improve the effectiveness of rural household financial asset portfolios but also optimize the allocation of rural household financial assets from the perspective of rural industrial development [6]. Ge et al. (2022) revealed that when digitalization encountered demographic and labor problems, it could force the labor market to optimize human resource management models, integrate and develop digital technologies and workforce, and play an active role based on the perspective of human–technology interaction [7]. For the research on Deep Learning (DL) technology in rural development and construction, Maduako et al. (2022) applied the improved Convolutional Neural Network to remote sensing image buildings for automatic data extraction of rural buildings [8]. Kim and Kang (2022) combined DL techniques with computer vision to identify scenes in rural tourism [9]. Based on the above research, it can be found that DL technology performs well in image recognition. However, there are drawbacks. The current study does not specifically identify the technical and economic challenges of building a digital village. It also fails to point out the environmental and resource problems caused by the construction of digital villages. Therefore, more research and work are needed. First, there is a need to strengthen digital infrastructure, especially in rural areas, to accelerate the rollout of high-speed internet. Second, digital skills training should be strengthened to improve the digital literacy of rural residents. Then, the development of digital agriculture and economy should be strengthened to promote farmers to change their consumption concepts and increase the added value of agricultural products. Finally, to pay attention to the impact of digital village construction on the environment and resources and promote the combination of digitalization and sustainable development.

The research objects are all traditionally backward rural villages, taking the most typical villages as examples to sort out their industrial structure and development information. This paper studies the rural industrial construction process in typical remote villages. Then, the unique elements of private entrepreneurship in the new era are clarified based on the general connotation of entrepreneurship. The main problems faced by traditional rural areas are analyzed, and the close relationship between traditional rural areas and cities is further discussed. In addition, theoretical models such as the equilibrium trap for low-income levels are introduced. A Neural Network (NN) model suitable for rural development is established. Finally, the conclusions are drawn. The innovation point is to establish a NN model aiming at the per capita annual income expectation and introduce the weights of influencing factors in the Genetic Algorithm (GA) learning model. Urban-rural relations are deeply studied. From the perspective of urban–rural integration, it is necessary to clarify the internal connection and development mode between the two and how urban integration policies affect urban–rural revitalization. In addition, the strategic needs put forward by the central government have been refined in terms of concept and implementation plan and also provide corresponding theoretical connotations for further in-depth research on urban and rural revitalization. A business starts under the conditions of researching new industries that can be developed in rural areas through digital empowerment based on DL to promote the development of rural areas. The research framework of this paper is as follows. Section 1 introduces the research background and previous research progress. It also proposes a research proposal and explains the role and innovation of this paper. Section 2 introduces the relevant theoretical model principles and the factor selection of the rural industry development model. Section 3 is the research methodology and research model. Section 4 is the experimental and result analysis. Section 5 is the test results and analysis, Section 6 is the discussion, and Section 7 is the conclusion.

2. Digital Model Design for Sustainable Development and Rural Industry Development

2.1. The Relationship between DL Technology and the Concept of Sustainable Rural Development

DL is an Artificial Intelligence (AI) technique that enables computers to simulate human cognitive processes to learn and recognize patterns from large amounts of data. DL technology has been widely used in many fields, including image recognition, Natural Language Processing (NLP), speech recognition, and object detection. DL can also play an important role in digitally empowering villages starting with the identification and classification of agricultural products. DL can efficiently process image data, and models can be trained to identify and classify agricultural products. For example, the image classification model can be used to automatically identify and classify different varieties of fruits and vegetables; thereby, simplifying market management and sales processes and improving the marketization of agricultural products. The second is agricultural production forecasting and management. DL can build predictive models to predict crop growth status, weather changes, and other information by monitoring various parameters and data in the agricultural production process. For example, meteorological data, soil moisture, and other information can be used to establish plant growth prediction models, provide farmers with production decision support, provide assistance on how to arrange agricultural production plans, and increase production. Then, there is agricultural robotics. DL can help control agricultural robots to automate various tasks. For example, using DL to train robots to recognize and analyze image and voice data allows agricultural robots to automatically complete various tasks in the agricultural production process, such as sowing, harvesting, and weeding. There is also agricultural supply chain management. Agricultural supply chain management systems can be built using blockchain technology and DL technology. The quality and safety of agricultural products can be ensured through anti-counterfeiting, traceability, and other technologies. DL algorithms are used to analyze and predict various data in the supply chain. It can accurately understand the market demand, make market forecasts in advance, and gradually achieve precision in agricultural production.

However, it should be noted that digitally empowering villages is not simply to apply ready-made technology directly to rural areas, but to customize the design and application based on the actual situation of rural areas. Appropriate scientific and technological means are selected in combination with AI technology to promote sustainable rural economic and social development.

The theory of sustainable development is a comprehensive and dynamic concept involving the economic, social, cultural, technological, and natural environments [10]. The connotation of sustainable development theory can be explained from the following points. The first is development. A sine qua non for sustainable economic development is development. Sustainable development does not negate economic growth, but it is necessary to re-examine the external impact of economic growth on the environment, realize the organic combination of economic growth and environmental and ecological improvement, and achieve sustainable economic growth. In the traditional sense, economic growth has mostly come at the cost of damaging the environment and ecology. Therefore, it is important to abandon the idea of development before governance and minimize or even completely eliminate the negative externalities of economic production on the environment. The second is to promote harmonious development. Based on the rational use of natural resources by human beings, it is necessary to adapt to the carrying capacity of nature, achieve green economic growth, and realize harmonious coexistence between man and nature. The harmony of sustainable development involves many aspects, including man and nature, man and society, and the human body and mind. In addition, people should also pay attention to the harmony of the individual's body and mind and pay attention to the harmonious development of the spiritual and material levels. Finally, it is important to focus on fairness. The important goal of sustainable development is to achieve the rational allocation of social resources and share the fruits of economic development. It includes not only people but also industries and countries. There is no absolute fairness between different individuals, but sustainable development theory requires relative fairness. Both overall moderate prosperity and common prosperity emphasize the relative fairness of resource allocation. The theory of sustainable development emphasizes the importance of harmonious coexistence between man and nature in economic development. The synergy of economic system, social system, and ecosystem has laid a certain theoretical foundation for the re-study of rural construction.

In summary, DL technology can effectively transform rural industrial structure, improve agricultural productivity, and promote sustainable development of rural areas. Meanwhile, it can also efficiently promote the development of rural information technology to comprehensively improve the effect of sustainable rural development. Therefore, this paper uses the digital empowerment rural background based on DL to explore and evaluate the development status of rural areas to provide a reference for the sustainable development of rural areas in the future.

2.2. Status Quo and Main Development Model of Traditional Villages

Many subjective and objective reasons cause the problems of economic backwardness and poverty of residents in traditional villages. The status quo of traditional villages is not optimistic. Although some villages have started to get rid of poverty and have become rich, and are actively carrying out resource exploration and industrial restructuring, many traditional villages are still in a backward state that has not been paid attention to [11]. In general, the status quo of traditional villages can be summarized into seven aspects, as shown in Figure 1.

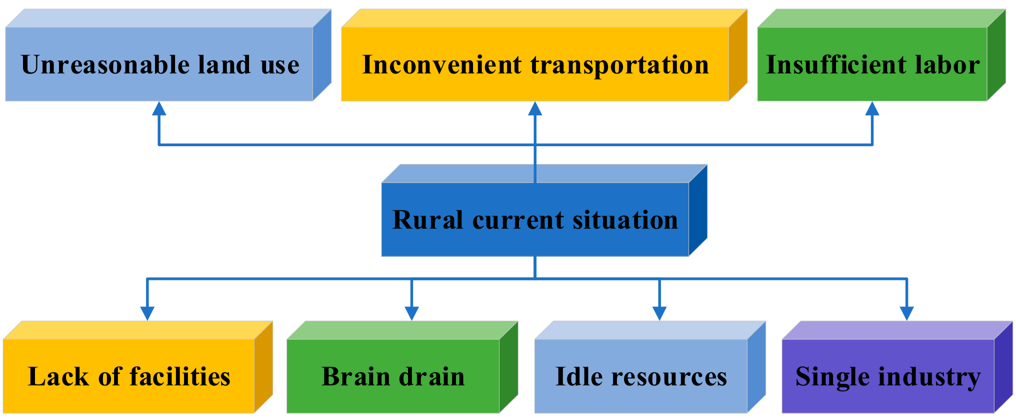

Figure 1. Status quo of traditional villages.

Figure 1 reveals several situations that traditional villages are currently facing. Different villages may have different situations, and specific problems need to be analyzed in detail. The following is an in-depth analysis of the basic characteristics and main problems of traditional villages. Different traditional villages have different characteristics, but they are generally backward and poor and mainly face several major difficulties: single labor force, dilapidated buildings, serious empty-nesting phenomenon, cultural decay, and conflicts between economic development and natural and cultural environmental protection [12].

International research on tourism, leisure agriculture, and rural tourism in remote villages is also very rich. Some studies have put forward the concept of sightseeing leisure agriculture and rural tourism. Sightseeing and leisure agriculture will be a new industrial model combining agriculture and tourism with villages as the carrier [13]. Modern agriculture is no longer a single industry engaged in agricultural production but needs to be combined with ecological environment construction, tourism civilization construction, and spiritual civilization construction for leisure and vacation to provide people with colorful rural life. The schematic diagram of rural agricultural land and construction land is demonstrated in Figure 2.

Non-gray region：agricultural land

grey area： construction land

Figure 2. Schematic diagram of rural agricultural land and construction land (non-gray region: agricultural land; gray region: construction land).

From Figure 2, from the perspective of urban planning, the spatial form of rural areas is fundamentally different from that of cities in the same region. The reason for this is that the countryside has a basic land type that is not found in general cities, namely agricultural land [14]. Agricultural land is the main production land and occupies a major position in the agricultural land structure. The scale of construction land in the countryside is relatively small, and farmers use gravel to build villages, roads, and public facilities. Therefore, the spatial relationship between rural farmland and building land can be conceptually simplified as the relationship between field and village. The principle of circular accumulation causality is that there is a causal relationship of circular accumulation among social and economic factors. Changes in one socioeconomic factor can lead to changes in other socioeconomic factors. The two changes influence each other, forming a cumulative and cyclical development trend. The vicious circle poverty theory is for both supply and demand. The interconnectedness of several economic factors can cause capital formation to turn into a vicious circle. The low-level equilibrium trap theory states that countries with low per capita income have slow population growth and low household savings. Increasing national income will lead to rapid population growth, resulting in lower per capita income and repeated cycles of low-level per capita income. From the perspective of economics, it is necessary to scientifically explain that the poverty and backwardness of traditional villages in developing countries are related to the labor force shortage and other reasons. From the theory of circular accumulation causality, vicious circle poverty theory, and low-level equilibrium trap theory, the root causes and mechanisms of the backwardness of traditional villages are analyzed [15]. Figure 3 displays the low-income level equilibrium trap model.

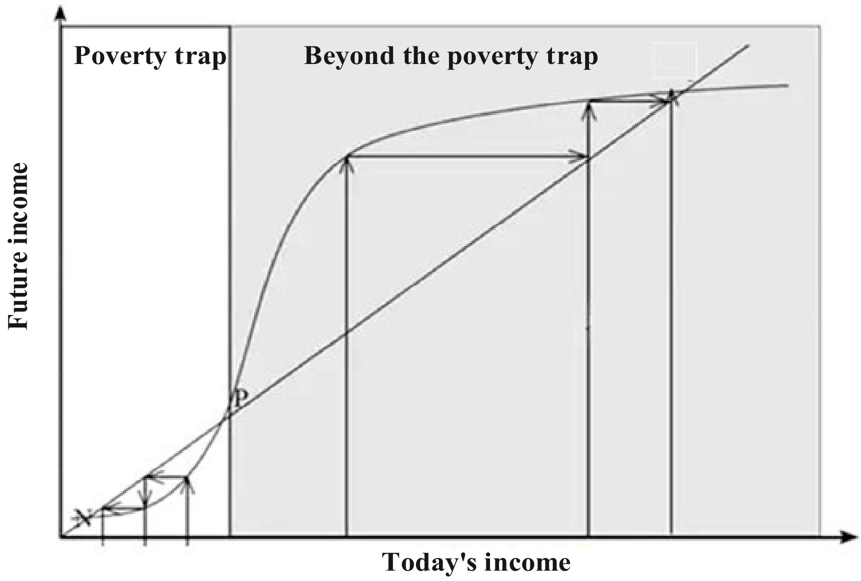

Figure 3. Low-income level equilibrium trap model.

Figure 3 indicates that the low-level equilibrium trap model is also applicable in many traditional villages. Each family often has two or more children due to some old-fashioned concepts in traditional villages, resulting in rapid population growth, while residents' income growth is slow or even regressive. The low-level equilibrium trap in traditional villages is caused by low per capita income and scarcity of capital. Traditional villages must deepen reforms, realize institutional innovation, and eliminate the possibility of a vicious circle at the source to get rid of poverty and come out of backwardness [16]. Accelerating the formation and agglomeration of capital, expanding the scale of the industrial economy, and increasing employment opportunities are effective plans to revitalize the countryside.

The five stages of new village development can be traced back to the early 1970s [17]. The first phase of construction work was roughly concentrated from 1970 to 1973, and the main work was to build roads for villages, repair residential houses, and cultivate food crops. The second period of key measures was approximately between 1971 and 1976. The third stage occurred between 1970 and 1980. The difference between urban and rural areas had gradually narrowed, and the local government had invested in strengthening the development of agriculture. Inter-regional cooperation had expanded, and rural economic formats had become colorful. During this period, diversified business formats were introduced for the rural economy, which greatly increased the rural economic income. In the fourth stage, the government further increased investment based on the third stage to optimize the industrial structure and industrial layout of farmers. Farmers were driven to increase their income by developing agricultural diversification. The fifth stage was dedicated to the construction of spiritual civilization in the countryside and the integration of rural and urban development. Citizens' social morality and legal concept had also been improved.

2.3. Element Selection of Rural Industrial Development Model Based on Entrepreneurship

The private entrepreneurial spirit in the new era has been endowed with new connotative characteristics by the times based on the general connotative characteristics of entrepreneurial spirit. Its unique elements can be grasped from the following five aspects; namely, the ability to achieve innovation from scratch, the sense of responsibility to deal with major emergencies, the craftsman spirit of pursuing high-quality development, the international vision of building a community with a shared future for mankind, and the cultivation of patriotism for global competitiveness. The particularity of rural ecological capitalization in underdeveloped areas is also the necessity for entrepreneurship to boost rural ecological capitalization in underdeveloped areas. The capitalization of rural areas urgently needs the participation of private capital. Entrepreneurship can guide capital to the countryside. The industrial environment under the guidance of entrepreneurship will lay a good foundation for the research here.

This section will first sort out the existing resources of a village and analyze its resource distribution and related data in various dimensions. In the construction process of these traditional villages, each dimension that will have an impact on the industrial structure layout is analyzed one by one, and a NN model is established. Then, the parameters in the NN are optimized by GA, and the optimal parameters of the NN in the high-dimensional parameter space are obtained. Finally, the weights of each dimension in the NN are extracted, and the optimization results of resource distribution and industrial layout are gained.

According to previous studies, the data of a village's spatial layout, roads, facilities, public service facilities, tourism development, and industrial development are used as the influencing factors (independent variables) affecting the per capita annual net income of the villagers. Given the vague description of the macroeconomic development policy and the main reasons for the development of national marketization and urbanization, the optimization goal of the NN is the most typical economic indicator to correctly express the advantages of a village's natural resources and industrial structure [18]. The average annual net income is the main indicator to reflect the increase in the income of the country's farmers, the expansion of agricultural reproduction, and the level of savings. It can also reveal the degree of economic development of a country and a place in a period, so it is chosen as the optimization objective (dependent variable) of this model.

Figure 4 implies that the village land is mainly forest land. The total amount of cultivated land and the scale of construction land is small, and the village pattern of the front courtyard and backyard makes the per capita construction land reach 165.7 square meters. The current rural construction land is divided into villager residential land, rural public land, and rural infrastructure land, mainly distributed in four villages within the town. The total land area of the construction project is 15.68 hectares, including 10.65 hectares of residential land for villagers, 1.95 hectares of rural public land, and 3.08 hectares of rural infrastructure land. Non-construction land also includes sea area, agricultural land, and other non-construction lands, totaling 926.83 hectares, including 169 hectares of arable land and 710 hectares of forest land. The spatial form and land use layout of the village are distinctive. The number of industry categories in the village is shown in Figure 5.

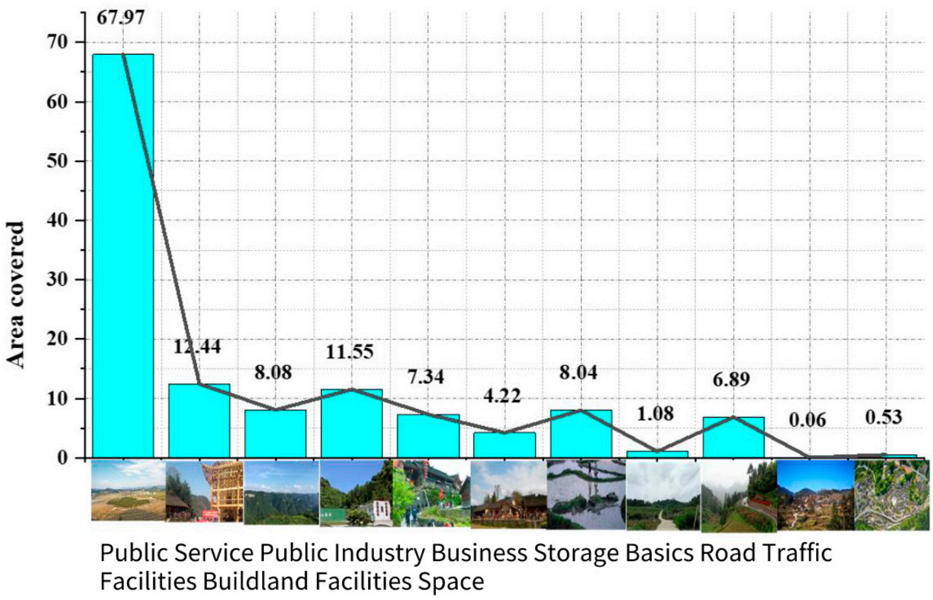

Figure 4. The proportion of construction land in the village with the status quo.

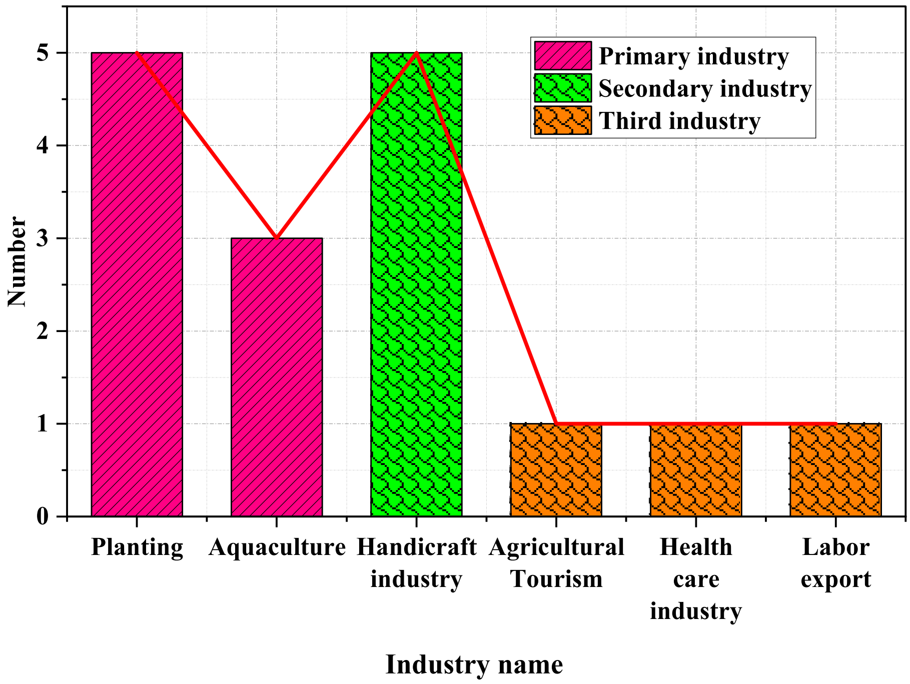

Figure 5. Number of industry categories in the village.

From Figure 5, in the family population size, the population size of small- and medium-sized families is the main body. It is proposed that the agricultural development of the village should integrate the functions of production, experience, and tourism through the analysis of the traditional agricultural development direction combined with the natural conditions here. In addition, the village should have a three-dimensional networked industrial development system such as agricultural planting, rural tourism, cultural experience, handicraft processing, mineral water processing, and labor export [19]. The family size of the village is revealed in Figure 6.

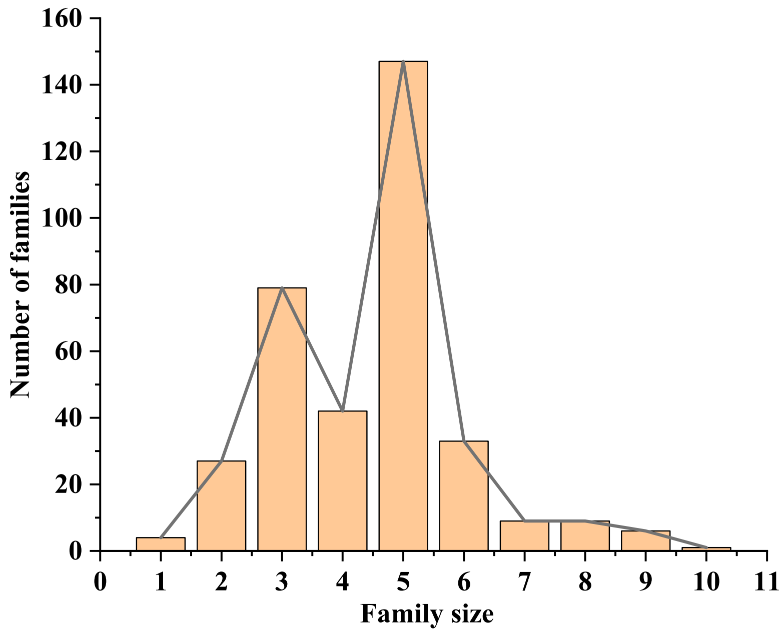

Figure 6. Family population size in the village.

Figure 6 manifests that the age structure of the family population in the village presents the characteristics of "two less and one more". The population of children, adolescents, and young adults is growing slowly and showing a downward trend. The number of elderly people is on the rise, and there is even a situation where the elderly population dominates. However, according to the survey data, the population of infants, teenagers, and young adults is smaller than the city's average, while the population of young children and girls is also declining.

The village has the largest proportion of cultural and sports facilities. The foothold of rural cultural construction lies in the cultural needs of the villagers. When promoting cultural construction, three-dimensional cultural network construction is destined to not only focus on a single cultural project [20] but also promote the multi-level construction of rural radio and television, cultural information, and cultural service networks. Cultural construction should cover a wide range. Moreover, the local public cultural network is established with the in-depth excavation, protection, and development of the local characteristic culture as the core. Figure 7 shows the catering and beds required by the tourism industry in each period.

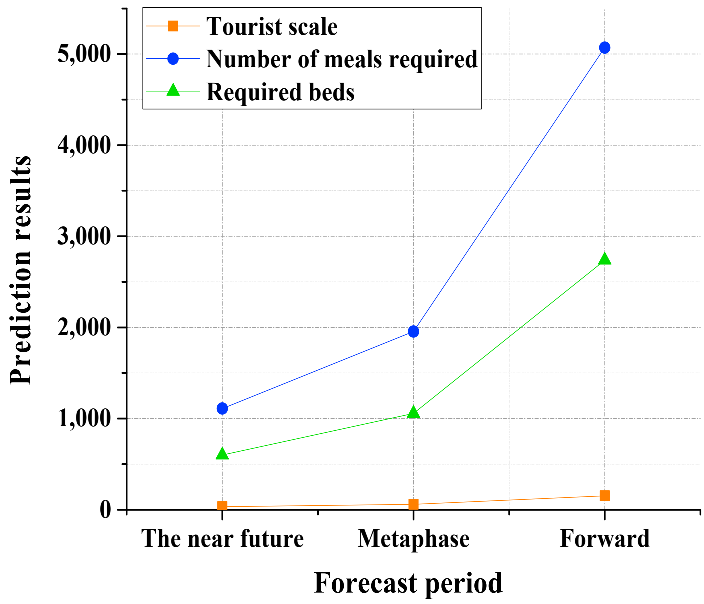

Figure 7. The catering and beds required for village tourism in different periods.

From Figure 7, the temporary increase of beds due to more tourists is the same as the number of statistical rooms. Only those beds that form the reception capacity of the hotel and can be used to receive tourists can reflect the reception capacity of the beds. The number of beds is widely used as an economic indicator to accurately reflect the reception capacity of foreign tourism hotels. The number of beds reflects the reception capacity of the hotel [21]. The village's tourism takes rural natural and humanistic objects as tourist attractions. There are resources such as beautiful landscapes, natural environments, architecture, and culture in rural areas. New tourism methods such as vacations and leisure and entertainment projects have been developed based on traditional rural leisure tours and agricultural experience tours. Therefore, the increase in catering and beds in its tourism industry indicates that it is developing well.

3. Research Methodology and Research Model Design

NN is an interactive parallel network formed by simplified units with a high degree of interactive adaptation, which can simulate the interactive response of the human neural cell network system to the real world [22]. The most basic organizational unit in biological NNs is the neuron pattern, the so-called simplified unit [23]. In a biological NN, it is assumed that all neurons are connected to another type of neuron. When it is active, it releases biochemical products to the neurons connected to it, affecting the potential within the neuron. If the potential of one of these neurons reaches a certain threshold point, it is also stimulated and becomes active, releasing biochemical products to the other neuron [24]. Figure 8 shows the McCulloch Pitts (M-P) neuron model.

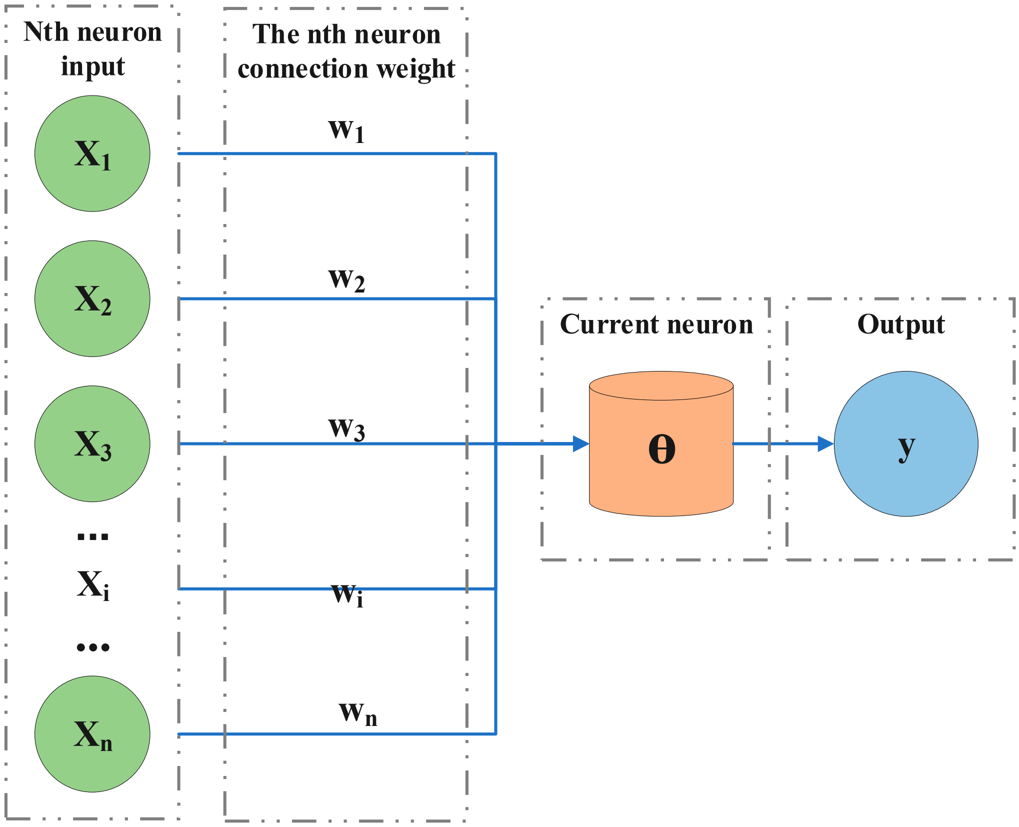

Figure 8. M-P neuron model diagram.

X represents the input of the neuron (the lower corner is the number of neurons. For example, $\mathbf{X_1}$ represents the input of the first neuron. $\mathbf{X_2}$ is the input of the second neuron. $\mathbf{X_3}$ is the input of the third neuron. $\mathbf{X_i}$ is the input of the ith neuron. $\mathbf{X_n}$ is the input of the nth neuron). w represents the connection weight of the neuron (the subscript represents the number of neurons. For example, $\mathbf{w_1}$ is the connection weight of the first neuron. $\mathbf{w_2}$ is the connection weight of the second neuron. $\mathbf{w_3}$ is the connection weight of the third neuron. $\mathbf{w_i}$ is the connection weight of the ith neuron. $\mathbf{w_n}$ is the connection weight of the nth neuron). θ represents the threshold of the current neuron. **y** represents the output value.

The simple model shown in Figure 8 is the classic M-P neuron model [25]. In this model, neurons receive input from countless other neurons, which are transmitted through weighted connections. The neuron compares the total input value received with the neuron's activity threshold and uses the activation parameter to process the neuron's total output [26]. The entire NN comprises countless neurons connected layer by layer according to a specific structure, and its learning rule can be obtained according to Equation (1).

$$W_i \leftarrow W_i + \Delta W_i \quad (1)$$

Equation (1) is the error backpropagation rule. W is the connection weight of each neuron. ΔW is the error value [27]. The training set is given by the Back Propagation (BP) algorithm.

$$D = \{(x_1, y_1), (x_2, y_2), (x_m, y_m)\} \quad (2)$$

Assuming that the output of NN is $\hat{y}_j^k$ [28] for training (x_k, y_k), then Equation (3) can be acquired.

$$\hat{y}_j^k = f\left(\beta_j - \theta_j\right) \tag{3}$$

Thus, the mean square error of the network on (x_k, y_k) is [29]:

$$E_k = \frac{1}{2}\sum_{j=1}^{\prime}\left(\hat{y}_j^k - y_j^k\right)^2 \tag{4}$$

It is concluded that (d + l +1) × (q + 1) parameters need to be determined in the network. They are d × q weights from the input layer to the hidden layer and q × 1 weight from the hidden layer to the output layer [30]. In each round of iteration, the generalized perceptron learning rule is used to update and estimate the parameters, and the update estimation equation of any parameter "V" is:

$$\text{"}V \leftarrow V + \Delta V\text{"} \tag{5}$$

The BP algorithm adjusts the parameters in the gradient direction of the target based on the gradient descent strategy [31].

$$\Delta W_{hj} = -\eta\frac{\partial E_k}{\partial W_{hj}} \tag{6}$$

The output affects the *j*th output layer neuron, output value $\hat{y}_j^k$ [32], and E_k.

$$\frac{\partial E_k}{\partial W_{hj}} = \frac{\partial E_k}{\partial y_j^k}\cdot\frac{\partial \hat{Y}_j^k}{\partial \beta_j}\cdot\frac{\partial \beta_j}{\partial W_{hj}} \tag{7}$$

According to the definition of β_j [33], the output value b_n is:

$$\frac{\partial \beta_j}{\partial W_{hj}} = b_n \tag{8}$$

At this time, the function has a good property [34], which satisfies the following relationship:

$$f'(X) = f(X)(1 - f(X)) \tag{9}$$

Then, Equation (10) can be got through Equations (8) and (9).

$$\begin{aligned} g_j\& &= -\frac{\partial E_k}{\partial \hat{y}_j^k}\cdot\frac{\partial y_j^k}{\partial \beta_j} \\ &= -\left(\hat{y}_j^k - y_j^k\right)f'\left(\beta_j - \theta_j\right) \\ &= \hat{y}_j^k\left(1 - \hat{y}_j^k\right)\left(y_j^k - \hat{y}_j^k\right) \end{aligned} \tag{10}$$

If Equation (10) is substituted into Equation (9), the updated equation for W_{hj} in the BP algorithm can be obtained [35].

$$\Delta W_{hj} = \eta g i b_h \tag{11}$$

The learning rate "η" ∈ (0, 1) controls the updated step size in each iteration of the algorithm. If it is too large, it will easily oscillate. If it is too small, the convergence speed will be too slow. The BP algorithm does the following for each training example. Input examples are provided to input layer neurons, and the signal is passed forward layer by layer until a result is produced at the output layer. Then, the error of the output layer is calculated, and it is back-propagated to the hidden layer neurons. Finally, the connection weights and thresholds are adjusted according to the foreign neurons in the hidden layer [36]. This iterative process loops until a certain stopping condition is reached. The basic flow of GA is shown in Figure 9.

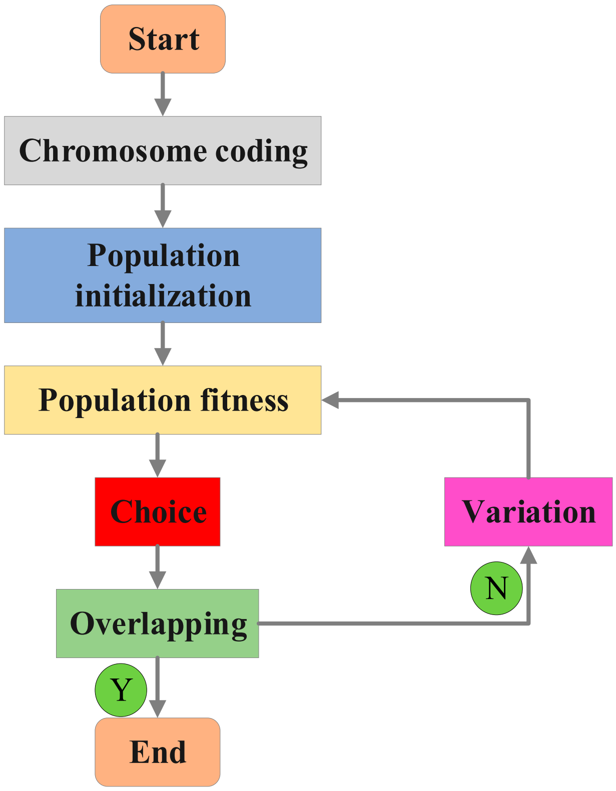

Figure 9. Basic flow chart of GA.

From Figure 9, in GA, chromosomes correspond to data or arrays, and a certain number of individuals form a group. The number of individuals in a group is called the group size, and the degree of adaptation of each individual to the environment is called fitness. The basic process of GA is divided into chromosome encoding, population initialization, evaluation of individual fitness function design in the population, selection, crossover, and mutation.

Using GA to solve NNs is mainly to optimize the parameters i, i, and w in NNs. The weights of the hidden layers in the NN training results are optimized, and the set of weights with the smallest difference between the simulation value and the actual value is found through the optimization results. The general solution steps for GAs are as follows. Randomly initialize parameters W_{hj} and encode the population, denoted as P(t). Calculate the fitness J of individuals in NNs. Replicate elite individuals and randomly cross and mutate selected individuals and coding units through roulette selection. The previous generation population is eliminated to obtain the next generation population P(t + 1). It is judged whether the population can meet the preset conditions, whether the number of iterations has been met, or whether the fitness of the species has converged [37]. If satisfied, it continues, and if not, the chromosomes are repeatedly decoded to return the optimal parameters of the NN. Therefore, the Genetic Algorithm-Neural Network (GA-NN) DL model is designed here. Therefore, it provides technical support for the research of this paper. In addition, the following hypotheses are made.

Hypothesis 1 (H1). *The GA-NN model has a positive impact on the development of digitally empowered villages.*

Hypothesis 2 (H2). *The GA-NN model can effectively optimize rural digital technology and improve the efficiency of rural digital technology.*

Hypothesis 3 (H3). *The GA-NN model achieves a great degree of innovation based on the existing technology model.*

4. Experiment and Result Analysis

The experimental environment for DL training is a computer of the Win 10 system. Anaconda's integrated Python environment is used to set up virtual environments. The DL algorithm model library Keras is installed and used for simulation. The data collected cover the period from 2009 to 2022. For some missing data, the method of taking the average of previous years and subsequent years is used to complete it, and the excess data are directly deleted. For the exception data caused by the collection error, they are corrected by deleting and supplementing the average. The average annual income of the entire village is used as an evaluation indicator (projection data for the output layer). NNs need to rely on a certain amount of data for training to ensure the reliability of the results. Too much data lead to excessive computational complexity. However, if only the collected data are trained, insufficient data volume will also lead to the insufficient fitting of the NN, resulting in a decrease in the confidence of the model. Therefore, in the training process of NN, the method of copying 100 sample data to the model for training is adopted. Gaussian noise is added to the sample to solve the overfitting problem of the model. Gaussian noise is usually a random distribution with a mean of zero. In NN models, Gaussian noise can be achieved by adding a dropout layer or noise layer to the input layer or hidden layer. The dropout layer randomly sets the output of a part of neurons to zero during training, which is equivalent to introducing some random noise into the input data to achieve the effect of preventing overfitting. The noise layer can add Gaussian noise to the input data during training or add Gaussian noise to the hidden layer, making the NN more robust to small perturbations of the input data.

The final NN model structure consists of an input layer, an output layer, and a hidden layer, and the number of neural units in the input layer is 65. Based on the dimensionality reduction of a large amount of data, the number of neural units in the hidden layer is set to 15. The number of neural units in the output layer is one, which is the annual income per capita in the study area. The model will be optimized using hidden layer weights from GA-NN training results. The optimization results are used to find a set of weights with the least difference between simulated and actual values. The steps for GA are as follows. The first step is to randomly initialize the weight adoption number. The second step is to code the population and calculate the fit of the individuals in the NN. The third step is to replicate elite individuals, use the roulette method to make selections, and randomly mutate and cross the selected codes and individuals. The fourth step is to survive the adaptors in the previous generation of the population and get the next generation of the population. The fifth step is to determine whether the population can meet the preset conditions. If this is met, proceed to step six. If not, repeat steps two to five. The sixth step is to decode the chromosomes and return the best parameters for the NN. Based on the above design, this paper will also conduct validation evaluation of the research model through cross-validation, divide the dataset into several copies, use one of them for validation each time, and use the rest as the training set. Through multiple validations, an average result can be obtained to evaluate the performance of the training method.

5. Research Results

5.1. Simulation Results of Rural Production Capacity NN Based on DL

The population size is set to 60, the number of iterations is 500, the crossover probability is 0.8, and the mutation probability is 0.01. Real encoding is adopted. Finally, the NN parameters optimized by GA are simulated. The NN simulation diagram obtained from the original data is shown in Figure 10.

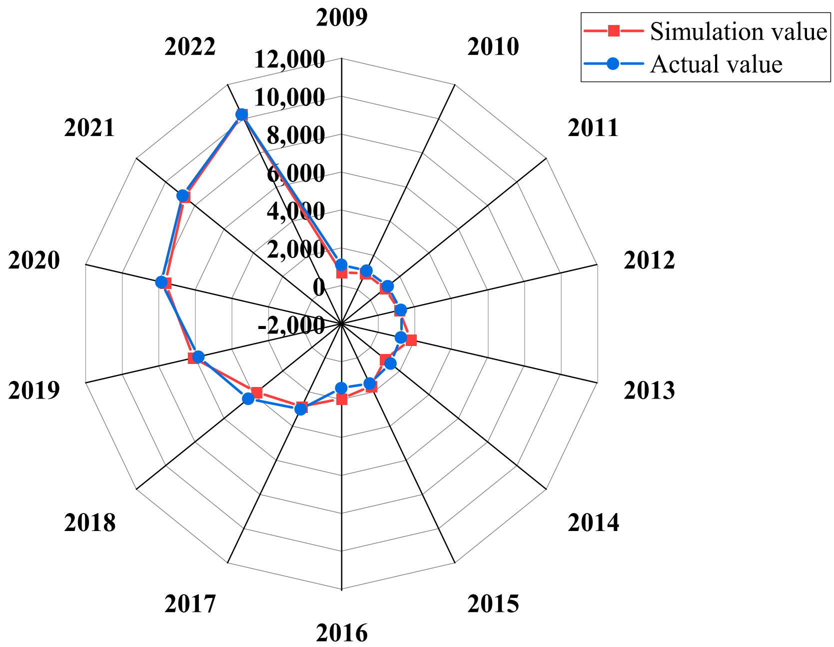

Figure 10. NN simulation diagram.

From Figure 10, during the 14 years from 2009 to 2022, the simulation results of the model are consistent with the actual data. The gaps are large in the six years of 2009, 2013, 2014, 2016, 2018, and 2019. The predicted values are high or low, and the numerical gap is between 200 and 600. The biggest gap was in 2016. The predicted value is 558.71 higher than the actual value. The overall predicted value curve is in line with the actual situation curve. The real data to restore rural production capacity can be simulated. The fitness performance of parameters and the search space distance of each generation population in the loss function is revealed in Figure 11.

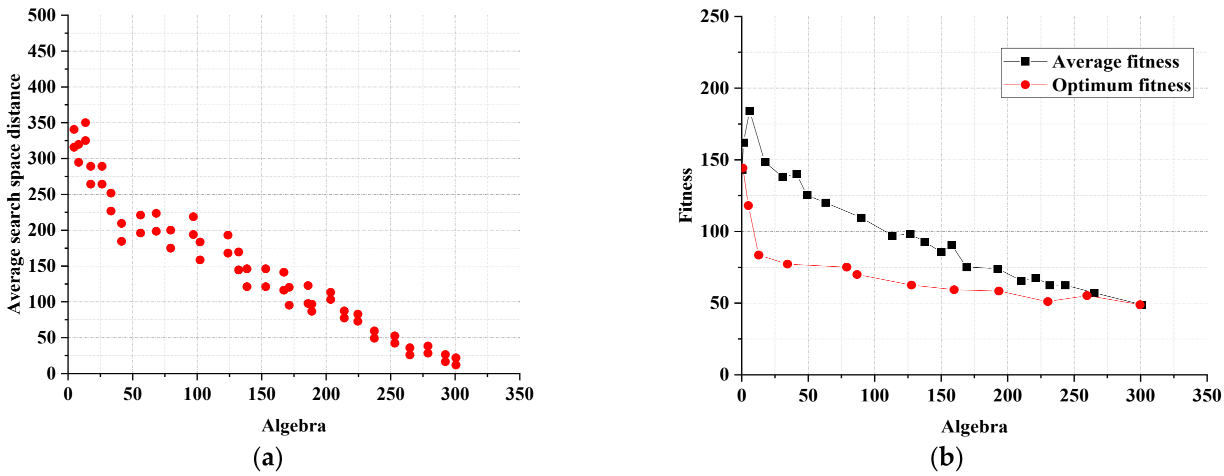

Figure 11. The fitness performance of each generation parameter in the loss function and the search space distance of the population. (**a**) Fitness performance; (**b**) population search space distance.

From Figure 11, the actual data are consistent with the simulated data, and the NN performs well. In the graph of fitness versus iterative algebra, the best fitness and average fitness of each generation converge consistently at the end. The search space diameter gradually converges to 0 from the initial 380. Therefore, the parameters are not trapped in the local optimal solution, and the obtained parameters are the global optimal solution in the definition domain.

5.2. Weighting Results and Analysis of Different Dimensions

The NN built by this model has a total of two layers of weights. The normalization method will be used to compare the weights intuitively. The data are processed into decimals between zero and one. The weight results are shown in Figure 12.

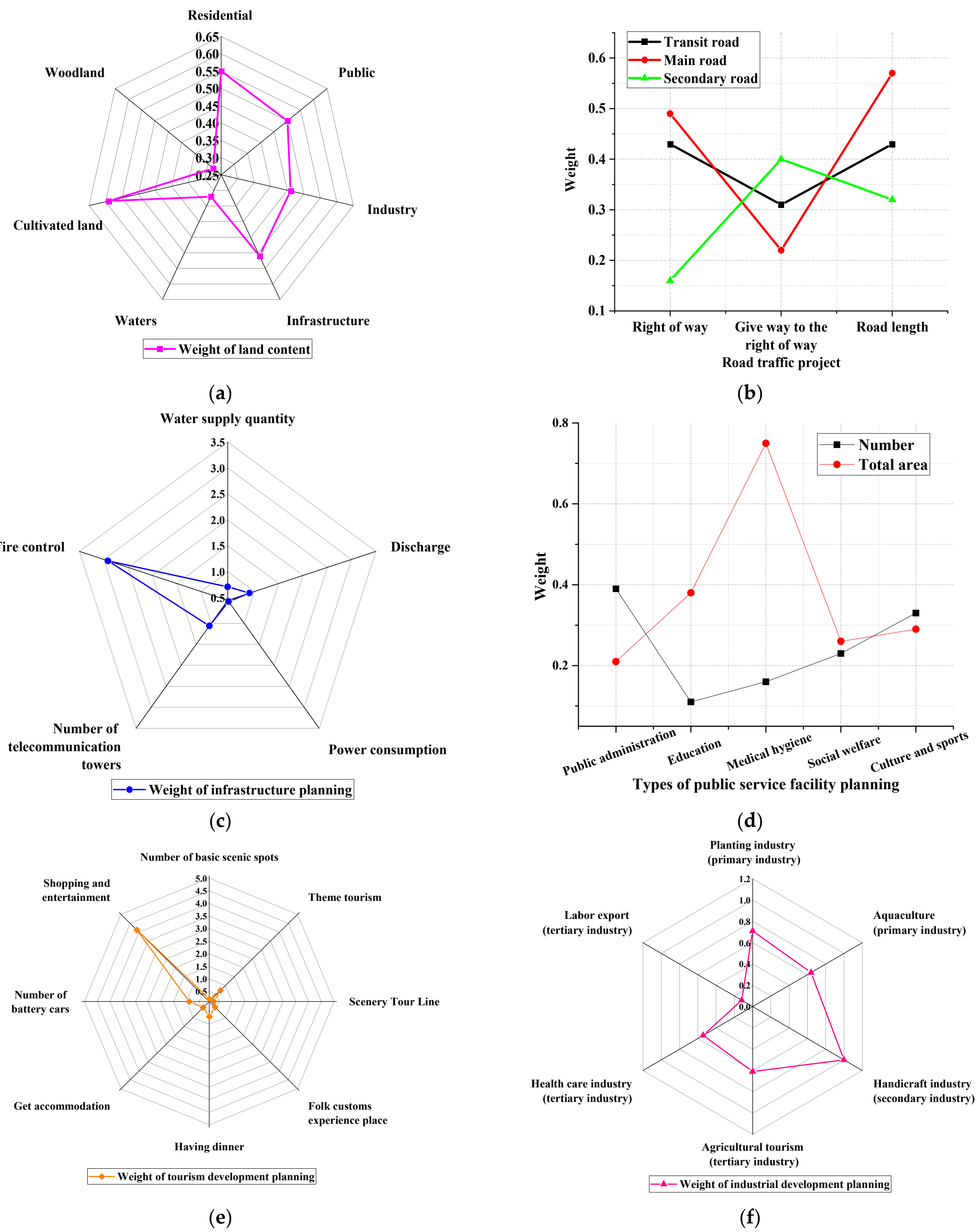

Figure 12. Results of various weights of the NN simulation. (**a**) Spatial layout planning; (**b**) road traffic planning; (**c**) infrastructure planning; (**d**) public service facility planning; (**e**) tourism development planning; (**f**) industrial development planning.

Figure 12 suggests that the mean of the weights is 0.45, and the standard deviation of the weights is 0.18. On the whole, the weights of all factors fluctuate little, and the average value of the weights can be referred to. If the weights in different dimensions are greater than the average value, it can be considered to improve the planning of this factor and promote the development of this factor. It will be conducive to improving the construction level of the village and the overall living standard of the villagers. From Figure 12, tourism, infrastructure, and transportation planning have high weights in the overall population, 7.79, 5.6, and 6.4, respectively. Energy should be devoted to developing these three sectors, and the development of each sector should be refined. For example, in the tourism industry, the weights of travel, shopping, and entertainment account for most of this sector. Therefore, the development of these aspects should be strengthened. Besides, the development of various aspects should be promoted according to the weight of different low dimensions. It is suggested that the construction of roads and transportation facilities can be strengthened in future village construction to ensure a good transportation foundation. In addition, it is important to increase infrastructure construction, improve the conditions of agricultural production, and promote the living standards of residents. It is necessary to encourage tourism development, carry out characteristic cultural activities to attract tourists, and increase economic income.

6. Discussion

In the study results, the predictions of the simulation model are consistent with the actual situation. This shows that the current state of village development can be predicted, and the results are feasible. The weight is in line with the actual development of the village in recent years, and tourism accounts for the highest proportion. Resources can be rationally utilized, and the industrial structure can be reasonably improved through mathematical models. The GA-NN model algorithm is accurate when calculating weights. The calculated training results correspond to the actual situation and truly reflect the development of the digital village. This paper provides researchable information for the future direction of rural entrepreneurship, which is conducive to planning the construction of future rural areas and achieving the goal of sustainable development. In addition, it is of practical significance to increase residents' income, realize rural poverty alleviation, and formulate a comprehensive model of rural reconstruction. Therefore, the specific impact of the current DL technology model on rural development is as follows: (1) the first is to improve agricultural production efficiency. DL technology can use sensors, monitoring, and other equipment to realize agricultural production automation and intelligence. Through the analysis and prediction of crop growth status and other data, it optimizes agricultural production plans, reduces waste in production links, and improves agricultural production efficiency. (2) The second is to promote the digital transformation of rural areas. DL technology can use modern information technology to improve the degree of digitalization of rural areas, realize digital management and digital operation, and provide strong technical support for the transformation and upgrading of the rural economy. (3) The third is to increase the added value of agricultural products. DL technology can add added value to agricultural products, improve the competitiveness of the agricultural products market, and promote the quality and brand value of rural agricultural products through intelligent classification, quality detection, and nutrient analysis of agricultural products. (4) The fourth is to promote the upgrading of rural logistics. DL technology can provide refined and personalized logistics solutions by integrating data from all links, reducing logistics costs, improving logistics efficiency, and meeting the logistics needs of rural supply chains.

In summary, DL technology can provide many new development opportunities for sustainable rural development. This requires governments and enterprises to make full use of these tools and means to develop and apply DL applications with rural characteristics. Thus, it creates a rich development space for rural areas, realizes the common upgrading of science and technology and economy, and injects new impetus into sustainable rural development. Compared with the research of Malebary and Khan (2021), this paper not only realizes innovative technical model design but also comprehensively evaluates the application and development of models [38]. Thus, the hypothesis proposed here has been fully proven.

In addition, the limitation of this paper is that the research scope is small. Therefore, to comprehensively optimize rural sustainable development goals, the following algorithms are proposed that can be used to develop digital industries in the future. The first is the decision tree algorithm. It can be used for crop planting management in agricultural production, such as predicting the harvest of different crops by predicting factors, such as temperature, rainfall, and soil fertility to help farmers carry out scientific irrigation and fertilization management. The second is the support vector machine algorithm. It can be used in agricultural forecasting, including epidemic, weather, and crop yield forecasting to help farmers formulate agricultural production plans. The third is the NN algorithm. It can be used for the diagnosis and prediction of animal diseases, such as by automatically monitoring animal behavior, health status, and other information in the surveillance video of the farm to assist farmers in the timely detection and prevention of animal diseases. The fourth is the ensemble learning algorithm. It can be used for agricultural data mining, prediction, and decision-making and helps farmers make scientific decisions by integrating multiple models and fusing information to improve the accuracy and reliability of decision-making. The fifth is NLP algorithms. It can be used to analyze the opinions and needs of farmers and rural residents. For example, it helps the agricultural sector and government understand the demands of farmers and rural residents and take effective policy measures by analyzing information, such as comments and messages on social media.

7. Conclusions

(1) Research objectives and main results: to solve the urgent problem of unbalanced rural economic development, the data of traditional and typical poor villages and the new connotation of entrepreneurship in rural revitalization are collected. Studies show that the tourism, transport, and infrastructure sectors are given high weights. Among them, the weight of tourism is as high as 7.79, indicating that the construction of tourism is one of the important factors to improve rural economic development. (2) The theoretical and practical implications: first, the theoretical significance of this paper is to provide a reference for the digital development of rural industries and promote the sustainable development of rural areas as a whole. Second, the practical significance of this paper lies in proposing an effective analysis of rural development problems and solutions to provide important support for sustainable rural development. The results show that GA-NN can quickly converge to the global optimal solution in high-dimensional space, and the weights of each factor can be obtained. (3) Limitations: the limitation is that rural digitalization is still in the research stage. If the weights of each indicator are clarified, the model can be upgraded to simple evaluation software for easy use in practice. (4) Future research directions: future research directions will focus on abstracting multi-objective operation optimization models into concrete mathematical numerical problems. Through mathematical models, the problem of how to optimize the use of resources can be solved. Mathematical models with minimal optimization will be introduced to deepen the development of entrepreneurship in rural revitalization. In addition, the resource allocation and industrial scale in traditional rural digitalization will also be discussed in depth. This paper has important social value and significance for exploring the traditional rural digital optimization development model.

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