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Original scientific paper

A Fuzzy Neural Network Approach for Evaluation of Wetland Restoration Programmes

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Abstract: Wetland restoration work is crucial for ecosystem development, and how to scientifically evaluate wetland restoration programmes is the key to improve the effectiveness of wetland restoration. In order to solve the problems of inadequate judgement and human influence in the evaluation of wetland restoration programmes, this paper proposes a wetland restoration programme evaluation model based on Fuzzy Neural Network method, which is based on fuzzy theory and combines the adaptive function and self-learning function of neural network to evaluate three wetland restoration programmes. The results show that programme B is better than programmes A and C and is suitable for long-term application in wetland restoration work in this area. It is concluded that the use of Fuzzy Neural Network model to evaluate the wetland restoration programmes is more accurate, more personalised, and has a better operation rate, which is an important means of evaluating the wetland restoration programmes and an important guideline to carry out the wetland work.

Keywords: fuzzy neural network; programme evaluation; wetland restoration

1 INTRODUCTION

Wetland ecosystem, as one of the globally important ecosystems, is known as the "kidney of the earth" [1]. Because of their ecological functions such as water conservation, water purification, biodiversity protection, flood and drought control, climate regulation and carbon sequestration, they play a crucial role in maintaining the ecological environment, food and water security of all countries. Being able to link water and terrestrial ecosystems and provide a series of irreplaceable ecological products for human life, it is regarded as one of the best ecological environments in the world [2]. Wetland ecological development is related to the ecosystem development, and the promotion of wetland protection and restoration has been the focus of the current global ecological protection [3]. In the current situation, China's coastal wetlands are facing a severe situation, the rapid economic development, climate change and human activities brought about by the huge challenges, resulting in the serious loss of coastal wetland resources; degradation is serious, there has been a sharp decline in the area, and cause of ecological and environmental problems [4]. The emergence of a series of wetland problems highlights the importance and urgency of wetland protection and restoration [5].

Wetland protection and restoration is an important part of ecological civilisation construction and an important content of ecological civilisation construction. The breakup and reduction of wetlands can cause serious environmental problems and affect the economy and people's livelihood. In order to curb the continued deterioration of the wetland environment, the Chinese government has taken a series of measures to promote the construction of ecological civilisation at all levels and to strengthen wetland protection and restoration. Since China acceded to the Convention on Wetlands in 1992, it has actively fulfilled the purposes and obligations of the Convention, promoted wetland protection and restoration, and facilitated the high-quality development of wetlands and the sustainable development of wetlands [6].

Table 1 Policies related to wetland protection

Name	Related content
National Wetland Conservation Plan (2022-2030)	In accordance with the requirements of the Wetland Protection Law on the preparation of wetland protection planning, it is formed on the basis of summarising and evaluating the national wetland protection work in the "13th Five-Year Plan", and is formed after in-depth investigation and research, and after fully soliciting opinions.
Law of the People's Republic of China on the Protection of Wetlands	Effective from 1 January 2021, this is the first law in China dedicated to the protection of wetlands. It specifies the principles, objectives and measures for wetland protection.
Law of the People's Republic of China on Prevention and Control of Water Pollution	Involves the protection and management of wetland water environments.
Law of the People's Republic of China on Environmental Impact Assessment	Environmental impact assessment is required for projects involving the development and use of wetlands to ensure the stability and healthy development of wetland ecosystems.
Regulations of the People's Republic of China on River Management	Unauthorised development and encroachment on wetlands is prohibited.
Regulations on Urban Greening	Require that urban greening should focus on the protection and restoration of the ecological functions of wetlands.
Regulations on State-level Nature Reserves	Involves construction and management elements of wetland nature reserves.
Wildlife Protection Law of the People's Republic of China	Protect wetland wildlife resources and prohibit destruction of wetland wildlife habitat.
Land Management Law of the People's Republic of China	Requires rational development and protection of wetland resources.
Water Law of the People's Republic of China	Involves the rational use and conservation of wetland water resources.

Most coastal cities have begun to implement wetland ecological restoration through hydrological restoration, soil restoration, bioremediation and other measures, and it has become a consensus to rebuild or restore degraded coastal wetlands, and good results have been achieved in China's wetland work under continuous efforts. According to China Wetland Research Report, China's wetland area will be about 41.20 million hectares in 2020, and China's wetland area has reached about 56.35 million hectares in 2023, which is an increase of 37.00%, and the National Wetland Protection and Management Symposium said that the wetland ecological restoration work has made great progress. Each wetland restoration programme has its theoretical feasibility, but the applicable conditions and implementation measures of different wetland restoration programmes will affect the final restoration effect [7]. Therefore, it is an important way to improve the wetland restoration programmes by carrying out tracking and monitoring of the ecological restoration programme and evaluating the wetland restoration status after the implementation of the programme.

Wetland restoration has been highly valued and achieved certain results, and the evaluation of wetland restoration effect is the recognition and foundation of ecological protection work. General evaluation methods, such as grey clustering method and fuzzy comprehensive evaluation method, have large human influence factors, which make the evaluation results have certain errors with the actual situation, while Fuzzy Neural Network has the advantages of self-learning and self-adaptive ability [8], by automatically adjusting the thresholds and weights of the network with the help of the existing data information, which reduces the influence of the human factors, and is able to better fit the relationship between the indexes and the programme level. In this paper, the study takes the restoration of wetland nature reserve as the object, collects various index data of the restoration area for analysis, and evaluates the wetland restoration programme by using the Fuzzy Neural Network model, with a view to objectively and accurately understanding the restoration status of the wetland, and providing reference opinions for the wetland restoration work.

2 LITERATURE REVIEW

Foreign research on wetland restoration has been carried out earlier, showing a continuous upward trend since 1981, but due to the initial stage, human understanding of the ecological function of wetlands is not comprehensive. However, after the United Nations Conference on Environment and Development (UNCED) proposed the serious degradation of the global ecological environment in 1992, the research on wetland ecological restoration and function has developed rapidly [9]. Domestic research on the restoration and reconstruction of wetland ecosystems was carried out later [10], but developed rapidly, and the international influence increased faster. Kirwan and Megonigal (2013) suggested that wetlands have important buffer value and negative feedback to global climate change, and effective wetland restoration will become an important means to cope with climate change [11]. At present, wetland restoration mainly focuses on the study of ecological restoration measures and techniques, including wetland substrate modification, hydrological restoration, water environment restoration and wetland habitat restoration, focusing on the use of its original self-repairing ability, supplemented by artificial restoration measures, so as to bring the wetland back to its original productive state and natural function [12]. Li et al. (2022) believe that in the future, biological joint restoration techniques will be promoted in wetland restoration work popularised [13]. Ecological restoration techniques can accelerate the wetland restoration process and better achieve wetland ecological development. Zhou et al. (2023) planned a wetland park based on the concept of sustainable development according to the application of ecological restoration techniques to wetlands [14]. Yang et al. (2013) believe that the rapid development of ecological restoration forces us to think about what kind of restoration is successful restoration, dynamically evaluating ecological restoration projects and enhancing the logic of indicators [15]. The International Society for Ecological Restoration (ISER) suggested that in order to accurately assess the effectiveness of ecological restoration, biodiversity, vegetation structure, ecological functions and ecological processes should be considered [16]. The paper clearly pointed out the significance of organisms in ecological restoration assessment, and conducting diversity evaluation can reflect the stability, species richness and perfection of wetland ecosystems [17]. Wetland ecosystem restoration can not only improve water quality, but also improve soil quality and promote socioeconomic development. Evaluating wetland restoration programmes helps wetland restoration work to be carried out more smoothly.

Feng et al. (2017) used grey clustering method to evaluate the ecological restoration effect of damaged or degraded coastal wetlands and assessed the restoration effect of mangrove-farming pond coupled ecosystems in Shenzhen [18]. Tulun (2020) identified the place of wetlands in the ecosystem after his field research revealed the clear role of wetlands in the disposal of waste generated by landfills [19]. Wu et al. (2022) comprehensively used the frequency analysis method, theoretical analysis method and expert consultation method to construct an evaluation system in order to evaluate the effectiveness of mangrove ecological restoration in China [20]. He (2021) proposed a green supply chain performance evaluation method based on the fuzzy comprehensive evaluation method, based on the theory to establish a model to evaluate the performance of green supply chain in economic, social and environmental aspects [21]. Li et al. (2019) proposed a health assessment model for electric power automation equipment based on Fuzzy Neural Network, using the adaptive function of neural network to solve the problems of simple assessment method, weak interpretability of assessment method and imprecise assessment effect in health assessment, and to provide a more accurate and personalised health assessment for individual equipment [22].

Through existing studies, it is found that there is a lack of comprehensive assessment methods and index systems for wetland ecological restoration projects, while the effectiveness of wetland restoration programmes is the most intuitive reflection in carrying out wetland restoration work, which can have a positive impact on the social economy. Fuzzy Neural Networks are widely used in prediction and assessment studies because of their strong technical applicability and stable operation. For the study of wetland restoration programme, fuzzy theory can be used to analyse the fuzzy set to describe the evaluation indexes, the affiliation degree of the data indexes to describe the wetland restoration situation, combined with the adaptive function of the neural network, to evaluate the wetland restoration programme, which has the potential to be widely applied. This research result is of great significance in clarifying the advantages of wetland restoration programmes, as well as developing efficient and advanced restoration technologies. It will help to provide feedback on wetland restoration programmes and promote the healthy development of the human habitat and the prosperity and stability of human social life.

3 FUZZY NEURAL NETWORK FUNDAMENTALS AND APPLICABILITY

3.1 Overview of Fuzzy Neural Networks

In real life, there are often a large number of fuzzy problems. High-speed computers can certainly solve some of the problems, but for a large number of imprecise controls, it is often difficult to solve the problem in a single or fixed way. The traditional solution based on the exact mathematical model has drawbacks, the combination of fuzzy theory and artificial neural networks can solve these problems. Fuzzy Neural Network combines fuzzy theory and artificial neural network, fully embodies the advantages of each, makes up for their respective disadvantages, and shows excellent ability in dealing with large-scale problems related to the application of fuzzy technology. Its essence is to convert the inputs of neural networks into fuzzy input signals and fuzzy weights after fuzzy system processing, and to convert the outputs of neural networks into intuitive and effective numerical values. Specifically, in the Fuzzy Neural Network, the inputs and outputs of the neural network are represented as the inputs and outputs of the fuzzy system, and the fuzzy system's affiliation function and fuzzy rules are added to the implicit nodes of the neural network, thus giving full play to the parallel processing ability of the neural network and the reasoning ability of the fuzzy system.

3.2 Fuzzy Neural Network Model Structure and Algorithm

The traditional Fuzzy Neural Network is generally divided into five layers, the first layer is the input layer, the number of nodes is the number of input variables. The second layer is the fuzzification layer, which fuzzifies the input variables. The third layer is the fuzzy rule layer, the number of nodes is the number of fuzzy rules. The fourth layer is the antifuzzification layer, which deblurs the fuzzy set. The fifth layer is the output layer. The Fuzzy Neural Network model established in this paper takes the fourth layer directly as the output layer, with a total of four layers of structure, which are the input layer, the RBF layer, the regularisation layer, and the output layer, as shown in Fig. 1.

The first layer is the input layer. The number of nodes in this layer is the number of input variables and the input values are passed directly to the next layer. Assuming that the input layer has a total of K neuron, which represents the K dimensional input vector, the input variables in the network are

$$x_i = [x_1, \dots, x_k]^T \tag{1}$$

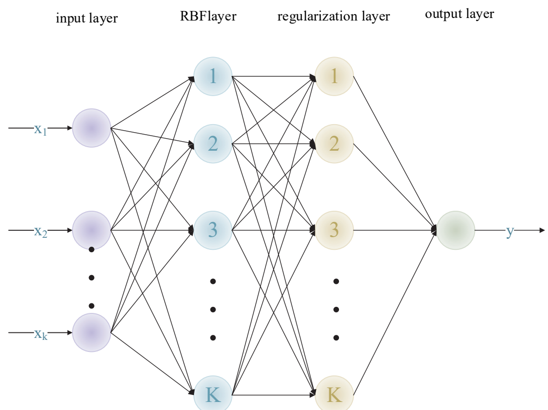

Figure 1 Fuzzy Neural Network (FNN) structure

The second layer is the fuzzification layer. This layer implements the fuzzification of the input variables, the division of the degree of affiliation. The number of nodes is the sum of the number of fuzzy sets for each input variable, and the connection weight between the neurons of this layer and the neurons of the first layer is 1. The affiliation function is used as the activation function of each neuron, considering that the Gaussian-type affiliation function has a greater advantage in the non-binary input inputs and spatial mapping [23]. Therefore Gaussian type affiliation function is chosen for the affiliation μA_j^i of each input variable x_j of the model.

$$\mu A_j^i = \exp\left(\frac{-(x_i - c_j^i)^2}{b_j^i}\right); \tag{2}$$

where $j = 1, 2, \cdots, k$, $i = 1, 2, \cdots, n$, c_j^i and b_j^i are the number of centres and widths of the affiliation function, respectively.

The third layer is the regularisation layer (fuzzy rule computation layer). Its nodes correspond to the *If* part (input part) and *then* part (output part) of the fuzzy rule. In the case where the rule is y_i, the fuzzy inference is it.

$$\begin{aligned} &R^i : \mathit{If}\ x_1 \text{ is } A_1^i, x_2 \text{ is } A_2^i \dots x_k \text{ is } A_k^i \\ &\mathit{then}\ y_i = p_0^i + p_1^i x_1 + \cdots + p_k^i x_k \end{aligned} \tag{3}$$

which A_j^i is the fuzzy set of the fuzzy system. $p_j^i (j = 1, 2, \cdots, k)$ is the fuzzy system parameters. y_i is the output obtained according to the fuzzy rules. *If* partly is fuzzy, *then* partly is deterministic.

This fuzzy inference indicates that the output is a linear combination of the inputs, and each degree of affiliation is fuzzy computed using the fuzzy operator as a concatenated multiplication operator.

$$\omega^i = u_{A_j^1}(\mathrm{x}_1) \times u_{A_j^2}(\mathrm{x}_2) \times \cdots \times u_{A_j^k}(\mathrm{x}_k) \tag{4}$$

where $i = 1, 2, \cdots, n$. ω^i is the weighting coefficient. The affiliation function $u_{A_j^k}(x_k)$ is R^i under the fuzzy set A_j^i. x have k dimension.

The fourth layer is the output layer. That is, the defuzzification layer, which takes the clarity of the affiliation values output from the previous layer and transforms them into the exact output values of the output variables.

$$y_i = \sum_{i=1}^{n} \omega^i (p_0^i + p_1^i x_1 + \cdots + p_k^i x_k) / \sum_{i=1}^{n} \omega^i \tag{5}$$

3.3 Applicability of Fuzzy Neural Networks

The neural network model can automatically adjust the structural parameters and change the mapping relationship according to the training samples, which has strong adaptivity and can achieve a variety of nonlinear mapping, better solving the problem of strong subjectivity in the traditional method, improving the evaluation accuracy and simplifying the solution process. Currently, neural network models are more widely used in evaluation problems. For example, T-S Fuzzy Neural Network is used to evaluate the flight skills of flight trainees [24]. With the continuous development of information technology and information management systems, technology research has been widely and successfully applied in practice [25], but the application of neural network model in the evaluation of wetland restoration programme is less. The results of wetland restoration programmes do not necessarily show some obvious results, but in reality are more of an improvement or degradation from the previous situation, and in most evaluations rely on human experience to deal with these fuzzy changes. In order to solve this kind of problem with ambiguity and difficulty to quantitatively describe the parameters, this paper innovatively applies neural network model and introduces the fuzzy theory to deal with it; the Fuzzy Neural Network is able to defuzzify the inputs and then carry out fuzzy inference. As the influencing factors of restoration programme evaluation, such as water quality, eutrophication, etc., are highly fuzzy and difficult to be described quantitatively, the Fuzzy Neural Network processes the inputs through the subordinate function, which can be described quantitatively, and can evaluate the wetland restoration programme well, and derive the situation of the wetland restoration programme, which can play a certain role in guiding wetland restoration related work.

4 EVALUATION MODEL FOR WETLAND RESTORATION PROGRAMME BASED ON FUZZY NEURAL NETWORK

4.1 Construction of Evaluation Indicator System

The evaluation of wetland restoration programme in this paper takes wetland restoration effect as the evaluation standard, and includes three levels of restored wetland water environment quality, wetland environment quality and wetland soil quality to construct the evaluation index system of wetland restoration effect (A). Among them, the water environment quality includes water quality condition (A_1), water body eutrophication (A_2); the wetland environment quality includes vegetation coverage (A_3), biodiversity (A_4); the wetland soil quality includes wetland area reduction rate (A_5), soil organic carbon density (A_6) six indicators (Fig. 2).

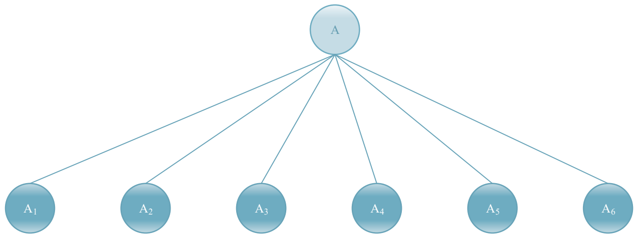

Figure 2 Diagram of the indicator evaluation system

The quality of water environment is measured according to the standard "Evaluation Methods of Surface Water Environmental Quality" (GB3838-2002), and the environmental quality of wetland and wetland soil quality are monitored according to the standard "Technical Specification for Wetland Degradation Assessment" (GB/T42532-2023). In the measurement process, the single-factor index method, the integrated nutrient index method for water bodies, and the landscape pattern index were mainly used. Biodiversity indicators were measured by the assignment method covering three levels of species multiplicity, relative abundance and rarity in the relevant literature [26], and the details of the expression method and measurement method of wetland restoration effect evaluation indicators are shown in Tab. 2.

Table 2 Wetland restoration effect evaluation indicators and measurement methods

Evaluation indicators	Methods of expression of indicators	Indicator measurement methodology
water quality condition A_1	Implemented in accordance with GB 3838, including Class I, Class II, Class III, Class IV and Class V.	one-way index method
water body eutrophication A_2	Implemented in accordance with GB 3838, including poor, medium, mildly eutrophic, moderately eutrophic, and severely eutrophic.	Combined nutrient index of water quality
vegetation coverage A_3	Vertical projection of vegetation (including leaves, stems and branches) on the ground as a percentage of the total area of the statistical area.	Landscape pattern index based on GIS, Fragstats
biodiversity A_4	Species abundance, relative abundance, rarity	Assignment method with reference to relevant literature
wetland area reduction rate A_5	Performed in accordance with GB/T 42532, including undegraded, lightly degraded, heavily degraded, and severely degraded.	Access to wetland resource survey data from wetland-related management authorities
soil organic carbon density A_6	Organic carbon stocks in soil layers of a given thickness per unit area	Determination of soil organic carbon density by potassium dichromate oxidation-spectrophotometric method

4.2 Indicator Normalisation

Since the evaluation indicators have multiple scales and cannot be compared directly, the data need to be normalised before network training to improve the training speed and sensitivity [27]. Different normalisation methods are chosen for indicators with different attributes, and the normalisation formula used in this paper is shown below.

a) extreme value processing

$$X_i' = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}} \tag{6}$$

b) standardised treatment method

$$X_i' = \frac{X_i - \bar{X}_i}{S_i} \tag{7}$$

c) vector norm law

$$X_i' = \frac{X_i}{\sqrt{\sum_{i=1}^{n} X_i^2}} \tag{8}$$

d) linear proportionality

$$X_i' = \frac{X_i}{X_i^*} \tag{9}$$

e) efficacy coefficient method

$$X_i' = c + \frac{X_i - X_{\min}'}{X_{\max}' - X_{\min}'} d \tag{10}$$

In the above formula, X_i' is the normalised value, and $X_i' \in [-1,1]$, S_i is the mean square deviation. X_i^* is a special point, generally tak $X_{\min}$, $X_{\max}$ or $\bar{X}_i$. $X_{\max}'$ and $X_{\min}'$ are the satisfactory and impermissible values of the indicator X_i'. c, d are known normal numbers, c the role of the transformed value of the translation, d the role of the transformed value of the zoom in or zoom out. Usually, it is taken as $c = 60$, $d = 40$.

4.3 Evaluation Model Construction

Wetland ecosystem is a relatively complex system, it is difficult to carry out direct evaluation, the selected evaluation indexes are more suitable for analysis with fuzzy theory, neural network has a strong self-learning function, which can adjust the system operating parameters according to the learning results of the historical data, the Fuzzy Neural Network model combining the fuzzy concepts and neural network can greatly enhance the effect of wetland restoration assessment, thus providing a more accurate, more personalised evaluation. The specific process is shown in Fig. 3, with the following steps.

a) Collation of relevant data following the implementation of the wetland restoration programme.

b) The output vector is determined to be 1. To classify the restoration effect, the wetland restoration effect was classified into five classes by referring to existing literature [29], as shown in Tab. 3.

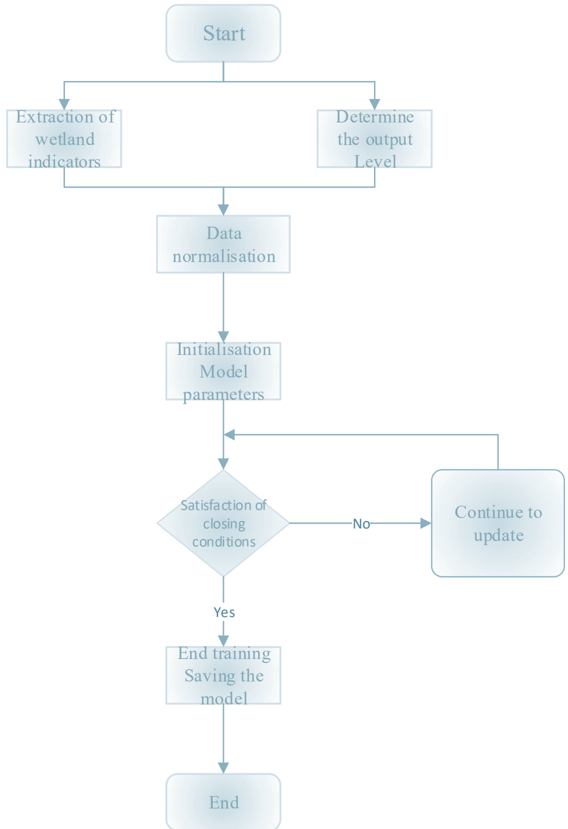

Figure 3 Evaluation process of wetland restoration effect

Table 3 Wetland restoration effect output ratings

Subject of evaluation	Wetland restoration effectiveness rating	Qualitative description of the grade
Wetland restoration effects	Class I (0-1)	At a lower level of restorative effect
	Class II (1-2)	At a low level of restorative effect
	Class III (2-3)	At an average level of restorative effect
	Class IV (3-4)	At a high level of restorative effect
	Class V (4-5)	At a higher level of restorative effect

c) Normalisation of data. Since the value domains of various types of indicators are different, it is necessary to select appropriate normalisation formulas for each indicator according to the specific indicator data, which not only eliminates the difference in the scale, but also accelerates the convergence speed of the model.

d) Initialise the model parameters to be trained. This includes the centre values c_j^i and width value c_j^i of the affiliation function and the weighting coefficients ω^i of the fuzzy rule and output layers.

e) Training the model and model testing. The training of the neural network model was carried out, with the six indicator data of the effect evaluation as input variables, the effect level as output variable, and the corresponding affiliation function as 12. The algorithm was constructed using the adaptive Fuzzy Neural Network model of

MATLAB R2022b. In order to ensure the consistency of the evaluation, using the equidistant uniform distribution method [28], the wetland restoration effect data were interpolated to generate 400 groups of samples, and 350 groups of its data were randomly selected as training samples. The training results are shown in Fig. 4.

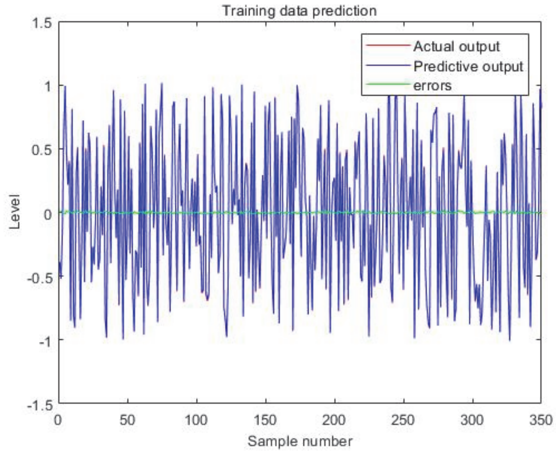

Figure 4 Model training situation

To carry out the neural network training, the affiliation function uses Gaussian type, the minimum error is set to 0, and the number of iterations is 100. The results in Fig. 4 show that the errors between the actual output and the predicted output are fluctuating around 0, and the error level is stable, indicating that the training results are ideal and the next validation operation can be carried out.

f) Testing the model. The stability of the performance of the Fuzzy Neural Network is tested by re-inputting the remaining 50 sets of data into the software as model test data.

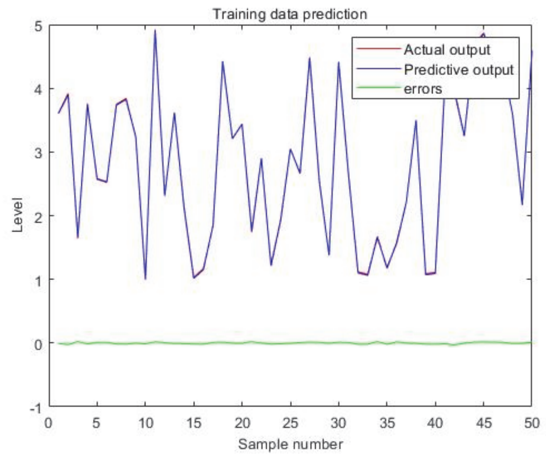

Figure 5 Performance stability test

The results in Fig. 5 show that the model error is small, the absolute error curve fluctuates around the value of 0, and the maximum absolute value error is less than 0.05, which meets the requirements of wetland restoration effect evaluation [30].

g) Save the model. Update the model parameters until the end conditions of model training are met. This paper chooses to terminate the training when the number of iterations reaches the set value, and sets the number of iterations as 100 times. Save the trained model to a file so that the model can be called when evaluating.

5 EXAMPLE EVALUATION OF A WETLAND RESTORATION PROGRAMME

5.1 Example Data

In this paper, the research scope is defined as different wetland restoration conditions in a region, the implementation of three wetland restoration programmes A, B and C in each quarter between 2015 and 2022 are collected, and six wetland restoration evaluation index data are investigated for wetland restoration effect assessment, calling the established Fuzzy Neural Network-based wetland restoration effect evaluation model.

5.2 Example Results

Based on the Fuzzy Neural Network model, the six indicators are calculated and the wetland restoration effect situation is output, as shown in Fig. 6.

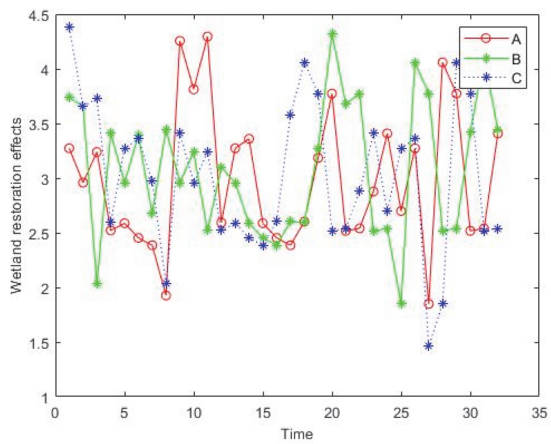

Figure 6 Evaluation of different wetland restoration options

The results in Fig. 6 show that, as a whole, the implementation of the three options fluctuated, with different implementation effects at different times, and there were periods of high levels of restoration, but most of the time periods tested were at an average level of restoration. Individually, the A programme did not show good results in the early stage of implementation, but reached a high level of restoration effect in the middle of implementation, and was in constant fluctuation in the late stage of implementation; the B programme was more stable than the A programme in the early stage of implementation, but it did not show the applicability of the programme in the middle of the process, and the restoration effect in the late stage of implementation was at a high level, with a higher overall restoration effect; the C programme, as a programme with good performance in the early stage, had a good restoration effect in the C, as a programme with good performance in the early stage of implementation, has average restoration effect in the middle stage, and the level of fluctuation in the later stage is higher. Overall, programme B performs better than the other two programmes in wetland restoration in this area, and is more suitable for guiding wetland restoration work in the long term.

In order to understand more intuitively and accurately the implementation of the wetland restoration programme, this paper presents the output results of the model in the form of a data table, which can be seen in Tab. 4.

Table 4 Results of the evaluation of the restoration effects of different programmes

Time	Programme number	Evaluation results	Restoration Level	Programme number	Evaluation results	Restoration Level	Programme number	Evaluation results	Restoration Level
2015.1	Programme A	3.33	IV	Programme B	4.21	V	Programme C	4.87	V
2015.4		2.96	III		3.91	IV		3.93	IV
2015.7		3.46	IV		1.9	II		3.9	IV
2015.10		2.45	III		3.81	IV		2.7	III
2016.1		2.56	III		2.96	III		3.33	IV
2016.4		2.35	III		3.79	IV		3.44	IV
2016.7		2.29	III		2.8	III		3.29	IV
2016.10		1.97	II		3.85	IV		1.9	II
2017.1		4.74	V		2.96	III		3.81	IV
2017.4		4.11	V		3.46	IV		2.96	III
2017.7		4.54	V		2.45	III		3.46	IV
2017.10		2.7	III		3.47	IV		2.45	III
2018.1		3.33	IV		2.96	III		2.56	III
2018.4		3.44	IV		2.56	III		2.35	III
2018.7		2.56	III		2.35	III		2.29	III
2018.10		2.35	III		2.29	III		2.56	III
2019.1		2.29	III		2.56	III		3.94	IV
2019.4		2.56	III		2.7	III		4.27	V
2019.7		3.46	IV		3.33	IV		3.95	IV
2019.10		3.95	IV		4.81	V		2.43	III
2020.1		2.43	III		3.96	IV		2.47	III
2020.4		2.47	III		3.95	IV		2.85	III
2020.7		2.85	III		2.43	III		3.52	IV
2020.10		3.52	IV		2.47	III		2.66	III
2021.1		2.66	III		1.69	II		3.33	IV
2021.4		3.33	IV		4.27	V		3.44	IV
2021.7		1.69	II		3.95	IV		1.25	II
2021.10		4.27	V		2.43	III		1.69	II
2022.1		3.95	IV		2.47	III		4.27	V
2022.4		2.43	III		3.49	IV		3.95	IV
2022.7		2.47	III		4.32	V		2.43	III
2022.10		3.52	IV		3.51	IV		2.47	III

As shown in Tab. 4, the effect of programmes A and C is lower than that of programme B. However, for guiding wetland restoration work it is necessary to update the programmes in time. It is necessary to understand the principle of mutualism of wetland species, respect the law of ecology itself, and grasp the degree of human control. In the implementation of the wetland programme, natural restoration should be the main focus as far as possible to reduce the damage to the environment. Pay attention to the water resources in the restoration area, increase penalties for pollution of wetland water resources, prohibit indiscriminate discharge of water, and strictly control the discharge standard of industrial wastewater. The reclaimed wetlands are gradually returned to wetlands, and illegal hunting and killing of wetland animals is prohibited. The use of bioengineering technology to carry out ecological reserves, the introduction of successful wetland restoration models, and the promotion of wetland protection. At the same time, it is necessary to increase the awareness of wetland protection and restoration, but also to develop wetland ecological economy, multi-level establishment of wetland industry chain, wetland parks and other eco-economy, so that wetland restoration and healthy development can serve for the benefit of mankind.

6 CONCLUSION

This study introduces the principle of Fuzzy Neural Network which combines fuzzy theory and neural network, and then applies the Fuzzy Neural Network to the evaluation of wetland restoration effect, and evaluates the wetland restoration programmes by establishing the index system, determining the model process and algorithm, and building the evaluation model. At present, this method is less frequently applied to the field of wetland restoration programmes evaluation. From the evaluation results, the B programme is more suitable to be applied to the wetland restoration work in this area compared with other programmes, and this evaluation result is basically in line with the actual monitoring data, which is accurate to a certain extent. From the evaluation method, the Fuzzy Neural Network has a strong interpretability of the indicators, and it can materialise the fuzzy data and produce more standardised results. From the evaluation process, the Fuzzy Neural Network is more applicable, the evaluation process is more standardised, and at the same time, due to its own self-adaptive and self-learning functions, the evaluation model is updated more timely. The above shows that the Fuzzy Neural Network has a certain objectivity and practicality in the evaluation of wetland restoration programmes, which is suitable to be applied in the field of wetland restoration programmes evaluation. In the future work, more effective features reflecting the effect of wetland restoration and the learning rate of the algorithm can be selected to further improve the evaluation effect of the model on the wetland restoration programmes.

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