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Short-term Evaluation of Eutrophication Based on GA-BP Model

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Abstract: After the impoundment of Three Gorges Reservoir (TGR), eutrophication has become the major problem of aquatic ecosystem degradation. In this study, a Genetic Algorithm-Back Propagation (GA-BP) model is developed for eutrophication evaluation in backwater area of Daning River, considering environmental evaluation factors including Total Nitrogen (TN), Total Phosphorus (TP), chlorophyll-a (Chla), secchi Disk Depth (SD) and potassium permanganate index (COD_{Mn}). The results evaluated by GA-BP model method are closely proximity to the results of comprehensive Trophic Level Index (TLI) method. These imply that the GA-BP model can precisely evaluate the water eutrophication due to the globe optimum, good convergence and fitness.

Key words: Eutrophication, evaluation, GA-BP

INTRODUCTION

The Three Gorges Project (TGP) has comprehensive effect on society-economics and eco-environment. To be sure, it brings about significant benefits in flood control, power generation. However, after the impoundment of TGR, the water level goes up and the velocity slows down and the water bloom occurs frequently in tributary Daning River of TGR (Zhang *et al*., 2010). Therefore, it is essential to search for a precise method for eutrophication evaluation.

The eutrophication evaluation methods mainly have Trophic State Index (TSI) method, grey clustering method, time series method and so on. However, the above eutrophication evaluation methods have some limitations because each affecting factor is uncertain, nonlinear and fuzzy. Artificial Neural Network (ANN) is perfectly suitable to deal with the complex nonlinear prediction and pattern classification problems due to the characteristics of strong self-learning, robust error toleration and accurate nonlinear approximation (Olabia *et al*., 2006; Bode, 2000). Back Propagation (BP) network is one of the most common used methods in ANN. It is a nonlinear Propagation (BP) network is one of the most common used methods in ANN. It is a nonlinear system with the features of adaption, self-learning and fault tolerance which has been used in water quality evaluation (Cao *et al*., 2008). However, it has been proved that BP can't guarantee consistency and precision and eventually reduces the reliability of the pattern prediction due to the disadvantages of slow convergence, over-fitting and especially local optimum (Yu *et al*., 2008; Huang *et al*., 2009). Genetic Algorithm (GA) is based on the evolutionism including natural selection, genetic crossover and gene mutation and it is a global search procedure from one population to another. As the algorithm continuously searches the parameter space, it is directed into the global solution for difficult non-linear functions (Zhu, 2003; Sexton and Dorsey, 2000). Considering of the above advantages, a GA-BP model method is used for eutrophication evaluation in Daning River.

MATERIALS AND METHOD

Study area: The TGR is a large reservoir in mid-west of china with a surface area of 79,000 km^2 and a storage capacity of 3.93×10^{10} m^3. The Daning River is located at latitude 31°02'-31°20' north, longitude 109°30'-110°01' east which is a very important tributary of TGR as well as a famous scenic spot. It is about 123km from the Three Gorges dam (Fig. 1). After the impoundment of TGR, the backwater submerged area is larger and longer and the velocity greatly decreases. Algae blooms have been observed in a backwater area of Daning River since June 2003 (Zeng *et al*., 2006). In this study, we will evaluate the water eutrophication about the backwater area of Daning River in 2004.

The GA-BP model method: The steps of GA including selection, crossover, mutation and implementing into population by global search. The BP network consists of one input layer, one hidden layer and one output layer.

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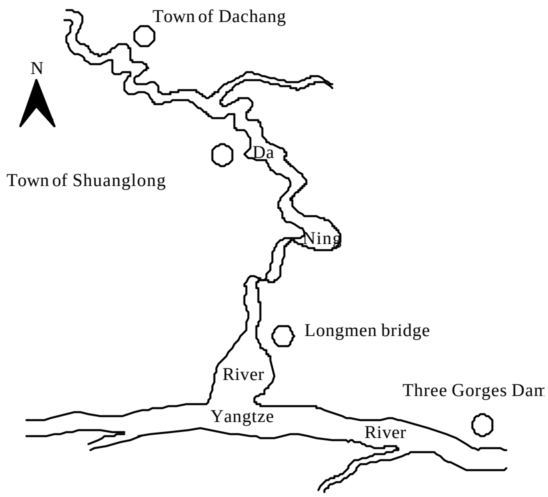

Fig. 1: Diagram for three gorges dam and daning river

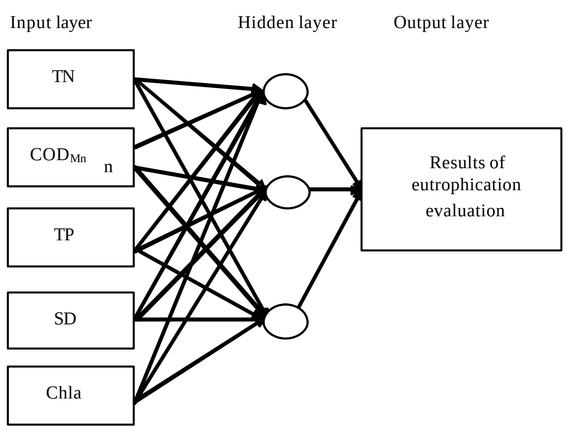

Fig. 2: Model of BP

Viewing the environmental evaluation factors as input layer nodes, the results of eutrophication evaluation represent the output layer nodes and hidden layer nodes are decided by trial. The BP model is shown in Fig. 2. All of the layers are composed of neurons which are interconnected with each other by weights. The process diagram of GA-BP model is in Fig. 3. The process of coupling BP with GA is as followed:

Step 1: The data sets are firstly normalized into [-1, 1] before training. The weights and thresholds of BP network are initialized and the fitness function is calculated

Step 2: Utilizing the fitness function to determine the direction and the range of further searches guarantying the global optimum and avoiding slow convergence and over-fitting (Li *et al*., 2011). Besides, the GA searches the optimal weights and thresholds by multiple iterative optimizations including selection, crossover and mutation

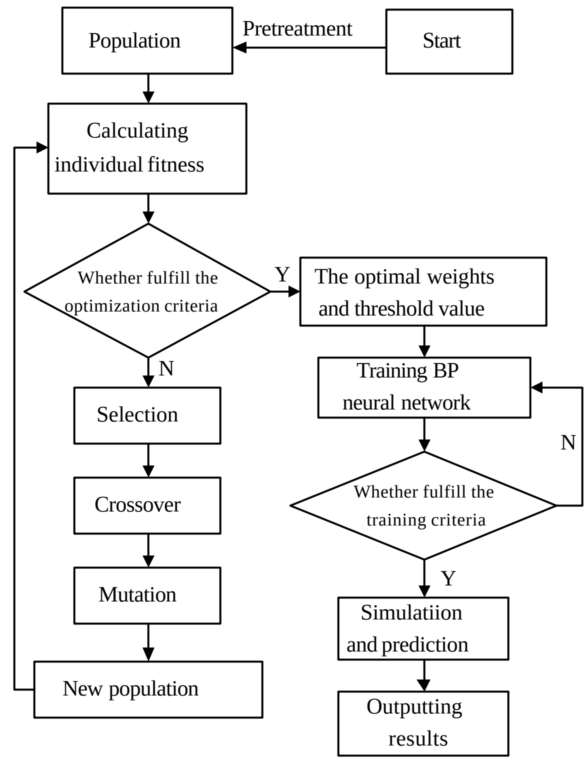

Fig. 3: Process diagram of GA-BP

Step 3: Training BP neural network and calculating the relative error of the network until the training results fulfill the optimal training criteria. Each time the training time of BP network is set to a smaller fixed value to improve the convergence rate of the algorithm

Step 4: Simulating and predicting the eutrophication and outputting the evaluation results

Environmental evaluation factors: The environmental evaluation parameters consist of water temperature, pH, TN, TP, COD_{Mn}, Chla, Suspended Substance (SS), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO) and so on (Zhang *et al*., 2010; Li *et al*., 2011). To optimize the relationship of eutrophication and relevant environmental factors, the above environmental parameters about water quality are selected by Principal

Table 1: Eutrophication evaluation indexes

Trophic state	SD (m)	TP (mg L^{-1})	TN (mg L^{-1})	Chla (mg m^{-3})	CODMn (mg L^{-1})	Output boundary values by GA-BP model
I	2.0	0.010	0.12	5	2.0	1.00
II	1.5	0.025	0.30	10	3.0	2.02
III	1.0	0.050	0.60	15	4.0	2.98
IV	0.7	0.100	1.20	25	7.0	4.01
V	0.4	0.500	6.00	100	20.0	4.95
VI	<0.1	>0.500	>6.00	>100	>20.0	5.98

Table 2: Eutrophication evaluation results of Daning River by different methods

Samples No.	SD (m)	TP (mg L^{-1})	TN (mg L^{-1})	Chla (mg m^{-3})	CODMn (mg L^{-1})	Output values by GA-BP model method	Eutrophication evaluation level by GA-BP model method	Eutrophication evaluation level by TLI method
1	2.00	0.020	0.780	16.87	0.83	2.52	III	II
2	1.96	0.060	1.181	12.43	1.65	2.82	III	III
3	1.90	0.040	0.870	22.90	1.17	2.84	III	III
4	1.25	0.050	1.811	53.43	2.77	4.28	V	V
5	1.00	0.120	1.650	60.90	4.26	4.48	V	V
6	0.67	0.110	1.580	76.88	3.52	4.61	V	V
7	0.60	0.120	1.670	82.64	3.46	4.64	V	V
8	1.60	0.840	1.046	7.15	2.08	2.63	III	IV
9	1.10	0.050	1.050	27.45	2.08	3.84	IV	IV
10	1.20	0.023	1.040	13.06	2.18	3.21	IV	III
11	1.30	0.033	1.140	17.26	2.12	3.28	IV	III
12	1.15	0.050	1.030	22.27	1.85	3.59	IV	IV
13	1.08	0.033	1.330	31.82	3.35	4.06	IV-V	IV
14	0.80	0.100	1.490	55.42	3.72	4.53	V	V
15	0.70	0.120	1.100	76.39	3.89	4.56	V	V
16	0.90	0.069	1.672	48.41	4.34	4.47	V	V

Component Analysis (PCA) using SPSS 20.0. Finally, TP, Chla, SD, TN and COD_{Mn} are considered as the main environmental evaluation factors.

Water assessment: According to the standard methods in eutrophication evaluation, the environmental evaluation factors and eutrophication state indexes can evaluate the water eutrophication. The eutrophication evaluation indexes table considering the five factors is showed in Table 1. In order to obtain enough learning samples, linspace function is used to homogeneous linear interpolation in each level of evaluation index, the total learning samples are 3600 groups. Randomly taking five-sixths of samples for training samples and the rest are testing samples in each level and defining the level I is oligotropher, II is mesotropher, III is eutropher, IV is light eutropher, V is middle eutropher and is hyper eutropher.

RESULTS AND DISCUSSION

Network output boundary value of each level: The input layer has five nodes and the hidden layer has three nodes while the output layer has only one node. The maximum generation is 100, the training time is 1000 and the total mean square errors in training set are 0.00423. The network output boundary value of each level by GA-BP model is 1.00, 2.02, 2.98, 4.01, 4.95 and 5.98, respectively (Table 1) which is taken as the standard value of the eutrophication evaluation index for Daning River. If the model output value is very close to the boundary value, it means that the tributary eutrophication is in the transition state in two adjacent levels.

The eutrophication evaluation results of Daning River are in Table 2. The results illustrate that the levels of eutrophication in Daning River are between mesotropher and middle eutropher which are closely proximity to the results of TLI method. These imply that GA-BP model has the ability of precise evaluation and good convergence and fitness which can be used in the eutrophication evaluation of reservoir tributary and make guiding significance in a more extensive scope in water quality assessment. On the other hand, it is in a state of middle eutropher for Daning River at sometimes. To some extent, it is necessary to take some favorable measures to avoid the deterioration of water quality.

For GA-BP model method, the scientific indicator system and the accuracy of evaluation criterion have a significant influence on evaluation results. In general, the GA-BP model is a quick and effective approach to obtain the accurate eutrophication evaluation due to a large number of samples and reasonable environment evaluation factors.

CONCLUSION

In this study, the GA-BP model has been applied for evaluating the eutrophication of tributary in TGR considering five environment evaluation factors including

TP, Chla, SD, TN and COD_{Mn}. The results demonstrate that it's sometimes in a state of middle eutropher for Daning River and favorable measures should be taken to avoid the deterioration of water quality. Moreover, the results evaluated by GA-BP model method are closely proximity to the results of TLI method due to elaborate evaluation criterion and scientific evaluation factors. This reveals that the GA-BP model can precisely evaluate the water eutrophication with the ability of globe optimum, good convergence and fitness which can be widely applied into the reservoirs eutrophication evaluation and make guiding significance in more extensive areas of water quality evaluation and prediction.

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