Study on Ecological Allocation of Mine Water in Mining Area based on Long Term Rainfall Forecast

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Abstract: Based on the mine water produced by mining, in order to improve the ecological environment, the optimal allocation of mine water resources is studied. In order to reduce the uncertainty of the calculation results of ecological water demand, the wolf colony algorithm neural network model is used for long-term rainfall forecast. Combined with the forecast annual rainfall, the ecological water demand is classified and calculated. The results show that the ecological water demand based on rainfall forecast can reduce the allocation of water resources in wet years to ecological aspects, so that the surplus water resources can be used in industries, irrigation and other aspects that can create economic benefits, and improve the utilization efficiency of water resources. The ecological allocation model of mine water based on long-term rainfall forecast can reduce the uncertainty of regional water resources allocation based on rainfall forecast, which has good guiding significance and practical value for the optimal allocation of water resources in arid and water shortage areas.

Keywords: Long term rainfall forecast; Mine water; Allocation of ecological water demand

1.Introduction

As an important energy in the world, coal has accounted for more than 70% of the disposable energy consumption in China and other developing countries. With the large-scale mining of coal resources, a large amount of mine water is produced along with the creation of huge economic and social benefits. More than 70% of China's mine water comes from large coal bases in water shortage areas and serious water shortage areas. The development and utilization of mine water resources has important practical significance to alleviate the contradiction between supply and demand of regional water resources. As unconventional water, mine water and other water resources cooperate to optimize the allocation of regional water resources has done a lot of research. Yin Shangxian[1] defined the concept of mine water and water resource allocation in mining area. Through the analysis of the feasibility of mine water resource allocation, three optimal allocation modes of mine water resources were proposed, namely, the combined mode of shallow drainage and supply, the mode of mine water recharge, and the mode of optimal allocation of mine water, groundwater and surface water. Zhang Chunhui[2] took the main high suspended solids, high salinity, high iron and manganese mine water in China's coal mining areas as an example, summarized the existing mine water treatment technology and its application status, introduced the sustainable treatment and resource utilization technology of mine water, and proposed the "all time and space mine water treatment and resource utilization technology" for the first time. Ji Yadong[3] took the Northern Shaanxi coal mining area as an example, discussed the treatment technology of mine water resources, the way of comprehensive utilization and the measures to further improve the comprehensive utilization of mine water resources. Based on the detailed analysis of hydrogeology, water resources and mine water inflow in Xiangshui mining area, Huang you[4] established the optimal allocation model of water resources in Xiangshui mining area with the sustainable development of social benefit, economic benefit and environmental benefit as the goal and the principle of system analysis. Xia[5] used the linear programming method, the large-scale system theory and the multi-objective decision-making theory with the society, economy, environment and water resources of the mining area as the comprehensive factors to establish the coordinated allocation model of water resources in Jiaozuo mining area, and put forward the ways and measures to solve the contradiction between supply and demand in the mining area.

At present, China's large-scale mining areas have invested capital and technology to implement the resource utilization of mine water, which is mostly used in industry, agriculture, ecology and other aspects. In order to reduce the uncertainty of optimal allocation of water resources, the traditional optimal allocation method and its improved technology can reduce the uncertainty from the perspective of mathematical analysis, but can not reduce the uncertainty of allocation results from the source of uncertainty. Because the mining area belongs to the area with poor water resources and fragile ecological environment, the ecological water demand is calculated based on experience or quota. The analysis shows that the actual ecological water demand is closely related to the annual precipitation. If the water resource allocation is based on the ecological water demand calculated by quota without considering the annual precipitation, there will be great uncertainty in the result of water resource allocation. It causes the waste of water resources. Taking Yuheng mining area in Shaanxi Province as the research area, this research studies the prediction of annual precipitation in this area, determines the ecological water demand based on the annual precipitation, and constructs the regional multi-source and multi-user mine water ecological allocation model based on long-term prediction. The results show that the ecological water demand based on the prediction results can effectively reduce the waste of water resources and the uncertainty of water resources allocation system.

2 Model Construction

2.1 Long term rainfall forecast based on astronomical scale factor

2.1.1 Selection of forecast factors

Due to the unclear physical mechanism, the selection of forecast factors is limited by time scale and space scale. The selection of forecast factors is lack of scientific demonstration, and the reliability and accuracy of forecast results can not meet the needs of engineering practice. In order to improve the accuracy of ultra long term forecast, it is necessary to find suitable forecast factors and methods. Stepwise regression method [6], multiple regression method [7], neural network [8], support vector machine [9] and other methods are combined with atmospheric circulation index, as the El Nino number, precipitation, temperature, humidity and other forecast factors to build models for rainfall or runoff forecast. The forecast factors have good applicability, good intelligence, high efficiency, which are difficult to obtain effectively. Moreover, the model construction is limited due to different factor foresight periods.

Each discipline can study natural disasters, but a single discipline has its limitations. For disaster research, the moon and the sun are in the best state [10]. In terms of astronomical scale, the layout of planets determines the variation of atmospheric circulation [11]. The movement of the sun, the earth and the moon has certain rules, and their future can be predicted. The future circulation situation can be predicted according to the movement and position of stars [12].

(1) Relative Sunspot Number

The sun is the nearest star to the earth, and its activity has the greatest impact on the flood on the earth. A large number of analyses show that the enhancement and weakening of solar activity will not only increase and decrease the circulation, but also the pattern of atmospheric circulation, and the hydrological factors will also change accordingly. The larger the relative sunspot number, the stronger the solar activity and the smaller the relative sunspot number, the weaker the solar activity.

(2) Declination of the Moon

The angle between the apparent orbit (white channel) surface and the equatorial surface of the earth (celestial sphere) is called the lunar declination angle (also known as the white red cross angle). The maximum declination angle of the moon produces 2.3 times the change of the earth's crust volume. The tide periodic change and crustal deformation caused by the lunar movement are the main causes of earthquake and heavy precipitation (or drought).

(3) 24 Solar Terms Lunar Date

The gravitational force of the sun and moon has a great effect on the earth, such as the solid, liquid and gas, which will lead to "land tide", "tide", "atmospheric tide" and so on. The relative motion of the sun and the earth is characterized by 24 solar terms. The 24 solar terms correspond to 15° per movement of the earth in the ecliptic. The lunar calendar date of 24 solar terms is almost the same every year, and the lunar calendar time corresponding to the solar term is introduced to forecast.

2.1.2 Treatment of forecast factors

(1) Sample classification

The method of sample classification is scale factor method. For multi-year rainfall series $X = \{x_1, x_2, ..., x_n\}$, the average annual rainfal $\overline{X}$ is calculated and multiplied by the scale factor corresponding to the feature of "abundant, flat and dry".Then, the sample classification which accords with the regional precipitation characteristics is determined.

$$\overline{X} = \frac{1}{n}(x_1 + x_2 + ... + x_n) \tag{1}$$

$$X_i = \overline{X} \cdot \alpha_i, (i = 1,2,3,4,5,6,7) \tag{2}$$

Where: X_i - indicates the limit value of extra high water year, high water year, partial high water year, normal water year, partial low water year, low water year and extra low water year. α_1 : The scale factor of the boundary between the extremely wet year and the wet year is 1.4. α_2 : The scale factor of the boundary between wet year and partial wet year is 1.2. α_3 :The proportion factor of wet year and flat year is 1.1. α_4 :The ratio factor of normal year and dry year is 0.9 . α_5 : The scale factor of the boundary between hemiplegia year and dry year is 0.8. α_6 : The scale factor of the boundary between dry year and extra dry year is 0.6.

(2) Processing and analysis of forecast factors

The astronomical scale factor, global cycle scale factor and basin scale factor are quantified. Sunspot relative number: the annual sunspot relative number is taken as the sample factor. Lunar declination angle: the maximum lunar declination angle of each year is taken as the sample factor. 24 solar terms: the 24 solar terms lunar date of each year is taken as the sample factor.

2.1.3 Forecast method

After the structure of BP neural network is determined [13], its weights and thresholds need to be obtained through training. BP neural network prediction is to assign the weights and thresholds contained in the optimal individual to BP neural network, so that the network can get prediction output after training and simulation. In order to improve the training speed and prediction accuracy of the neural network, the intelligent optimization method can be used to optimize the parameters between layers of the network to determine the optimal parameters, and the wolf colony optimization algorithm can be used to determine the initial values of the neural network parameters. Using GWO to optimize BP neural network can effectively improve the accuracy of parameter estimation, reduce the learning time of neural network and improve the effect of fitting prediction. If the error is large after several optimization iterations, the error is taken as the objective function, and the prediction factor is taken as the input factor to carry out the quadratic fitting prediction. The final prediction result is obtained by superimposing the first prediction result with the second prediction error.

The steps of Optimizing BP neural network with GWO model are as follows:

(1) The structure of the neural network is initialized. The three-layer neural network is used as the network structure. The number of neurons in the input layer is n_1, the number of neurons in the hidden layer is n_2, and the number of neurons in the output layer is 1, where $n_2 = 2 \times n_1 + 1$. The weights and thresholds are initialized randomly in [- 0.5,0.5] interval.

(2) Initialize the individual wolf group, determine the upper and lower limits of artificial wolf (*ub*, *lb*), population size *n*, the maximum number of iterations $I_{max.}$ Determine the dimension *n* of wolf vector based on the number of parameters, and determine the head wolf, probe wolf and fierce wolf based on the fitness of individual Wolf group.

(3) The individual evolution of wolves, through exploring the behavior of wolf wandering, fierce wolf rushing, siege behavior and updating behavior of wolves, constantly updates the position of individual wolves, and constantly updates the best individual wolf, which makes the individual wolves evolve in the direction of optimization, that is, the direction of optimal fitness.

(4) If the condition of the maximum number of iterations or the termination of iterations is satisfied, the iteration is stopped. Otherwise, step 3 is repeated until the optimal parameter vector is found.

2.2 Calculation of ecological water demand based on long term rainfall forecast

2.2.1 Calculation of ecological water demand based on quota method

For the calculation of ecological water demand in the mining area, the ecological objects are mainly rivers, wetlands, Haizi, ecological water surface and municipal road greening in the mine field and around the town. After treatment, the mine water can be used in ecological projects such as river lake wetland water supplement, road watering and greening.

(1) Water replenishment of lakes and ecological water surface: according to relevant design specifications and with reference to the design and operation experience of similar projects, the water replenishment of lakes and ecological water surface is calculated according to the water depth of 1.5-2m and three water changes per year. The calculation formula is as follows:

$$W = n \times A \times h \tag{3}$$

In the above formula: W - water supply of the lake ,10000 m3;

n -the number of annual water replenishment is 3;

A -water surface area, m^2;

h -the depth of water, m, it is 1.5 ~ 2.

(2) Water supplement amount of Haizi and wetland: it is calculated according to the relevant requirements of guidelines for ecological water demand assessment of rivers and lakes and code for calculation of ecological water demand of rivers and lakes. The calculation formula is as follows:

$$W = 10 \times A \times F \tag{4}$$

In the above formula:： W -water supply of Haizi and wetland, 10000 m^3；

A -area of Haizi and wetland, m^2；

F -evaporation-precipitation, m.

(3) River water supplement: 10% - 30% of annual runoff.

(4) Water demand of urban roads and greening: according to the relevant provisions of the code for design of outdoor water supply, the quota of green space and road watering is $2L/m^2 \cdot d$, and the watering is 180 days a year. Automatic and intelligent mine water sprinkler and drip irrigation system is adopted for green space irrigation.

(5) Water supplement amount: take 10% of natural runoff as the ecological water supplement amount.

2.2.2 Ecological water demand based on long term rainfall forecast

Based on the classification of regional rainfall forecast, the value of ecological water demand based on forecast can be calculated by the proportion of classification according to the results of rainfall forecast.

$$T_i = \overline{T}_i \cdot (2 - \alpha_i), (i = 1,2,3,4,5,6,7) \tag{5}$$

In the above formula: T_i -ecological water demand corresponding to the level of wet and dry precipitation. $\overline{T}_i$ -ecological water demand based on quota calculation. α_i -The meaning is the same as above.

2.3 optimal allocation of water resources

2.3.1objective function

The optimal allocation goal is to achieve the best comprehensive benefits such as economic benefits, environmental benefits and social benefits.

$$f(X) = \text{opt}\{f_1(X), f_2(X), f_3(X)\} \tag{6}$$

Objective 1 (economic benefits): the net economic benefits generated by water supply of different industries in different level years are the largest.

$$\max f_1(x) = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{I(k)} \left(b_{ij}^k - c_{ij}^k\right) x_{ij}^k \alpha_i^k \beta_i^k w_k \tag{7}$$

In the above formula: x_{ij}^k is the water supply of water source *i* to users *j* of subclass *k* (10000 m^3).b_{ij}^k is the water supply of benefit coefficient of unit water supply *i* to users *j* of subclass *k* (yuan/m^3).c_{ij}^k is the water supply of cost coefficient of unit water supply *i* to users *j* of subclass *k* (yuan/m^3) .α_i^k is the water supply sequence coefficient of water source *i* ,subclass *k* .β_i^k is water equity coefficient to users *j* of subclass *k*. w_k is the weight coefficient of subclass *k*.

Objective 2 (social benefits): the total water shortage of water supply system in each level year is the minimum.

$$\min f_2(X) = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \max[0, D_j^k - \sum_{i=1}^{I(k)} x_{ij}^k] \tag{8}$$

In the above formula: D_j^k is the water demand of subclass *k* user *j* (10000 m^3) .

Objective 3 (environmental benefits): the sum of COD emissions of each sub category in each level year is the minimum.

$$\min f_3(x) = \sum_{k=1}^{K} \sum_{j=1}^{J(k)} \sum_{i=1}^{I(k)} 0.01 d_j^k\, p_j^k x_{ij}^k \tag{9}$$

In the above formula:d_j^k is the chemical oxygen demand (COD) content in unit wastewater discharge of subclass k ,user j (mg / L). p_j^k is sewage discharge of users *j* of subclass *k*.

2.3.2 constraint condition

(1) Water supply constraints: water supply of water source is less than or equal to its available water supply. (2) The external water supply of water resources is less than or equal to its maximum water supply capacity. (3) The water demand capacity of users is limited, and the water supply capacity of users is less than or equal to the water demand capacity. (4) Water quality constraints, the concentration of pollutants discharged by users is less than or equal to the specified concentration of pollutants discharged up to the standard. (5) Non negative constraint, the water supply to users is greater than or equal to 0.

2.3.3 model parameter

The order coefficient of water supply reflects the limited degree of water supply of water source relative to other water sources. Now the limited degree of each water source is transformed into a coefficient in the interval of [0,1], that is, the coefficient of water supply sequence [14]. The user equity coefficient represents the priority of water supply for users relative to other users, which is related to the priority of water supply for users. According to the nature and importance of users, the order of water supply can be determined.

2.3.4 Benefit and cost coefficient

(1) Benefit coefficient

The benefit coefficient of industrial water use adopts the allocation method of total industrial output value [15]. The benefit coefficient of agricultural water use is determined by multiplying the benefit of agricultural production after irrigation by the water conservancy sharing coefficient. The benefits of water use for living, environment and public facilities are indirect and complex which they are not only economic factors, but also social benefits. It is difficult to determine the benefit coefficient. According to the allocation principle of priority of domestic and environmental water, this paper gives a larger weight in the calculation to express its benefit coefficient.

(2) Cost coefficient

Users who take water from waterworks take water price as their cost coefficient. The sum of water resources fee, sewage treatment fee and water pumping cost is taken as the cost coefficient for users who take water from their own wells. Users who take water from water conservancy projects take the sum of water resources fee, sewage treatment fee and water conveyance cost as their cost coefficient. The fee coefficient of agricultural users is determined with reference to the water fee collection standard.

2.3.5 Model solving

The water resources optimal allocation model established above is a multi-objective optimization model of multi-source and multi-user water resources. The scale of this model is large, and because of the existence of association constraints in various industries, the solution of the model is more complex, so the wolf colony algorithm is used to solve the problem. The core of its solution is the use of penalty factor in the modeling, which makes the variable that does not meet the demand of water supply given a larger penalty factor.

3 Introduction of study area

Yuheng mining area, the national key coal base, is mainly distributed in Yuyang District, Yulin City, Shaanxi Province. It is a dry and water shortage area with fragile ecological environment. The northern area of Yuheng mining area is mainly distributed in Xiaojihan, hongshiqiao, bulanghe and Balasu towns. Mining will produce mine water. At present, the mine drainage water used by coal mining enterprises in Yushen mining area is mainly used for their own fire fighting, dust removal, coal washing, road watering, greening, water for supporting enterprises and agricultural irrigation in surrounding villages and towns. The mine water in Yuheng mining area is used for ecological restoration, which is based on the experience of the staff. The lack of quantitative concept makes it difficult for the mine water to be used for ecological restoration. Moreover, the traditional calculation results of ecological water demand do not consider the annual actual precipitation, which makes the calculation results of ecological water demand have a large gap with the actual demand, It will result in unreasonable allocation of water resources and waste of water resources. Yuheng mining area only gives the rules of water distribution in the allocation of mine water, and lacks quantitative water distribution index as support, so the allocation result is not optimal. How to achieve the maximum benefit of water distribution is the core problem to promote the effective utilization of resources. Due to the water distribution process involving multi-source and multi-user, the calculation amount is large. At the same time, in order to reduce the waste of water resources and promote ecological restoration in arid areas, it is necessary to build the ecological allocation model of mine water based on long-term rainfall forecast.

4 Model application

4.1 Rainfall forecast in Yulin area

4.1.1 Rainfall classification

Based on the rainfall series of Yulin City from 1957 to 2018, the standard of classification is calculated by using the method of sample classification, as shown in Table 1. The rainfall of Yulin city can be predicted based on the classification results.

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4.1.2 Rainfall foreecast

Based on the sunspot relative number, the declination angle of the moon and the 24 solar term lunar date as the forecast factors, the average rainfall of Yulin and Shenmu meteorological stations in Yulin area is taken as the rainfall of Yulin city. The model is constructed by using the rainfall from 1957 to 2013, and verified by the rainfall from 2014 to 2018. The model is trained with the factors and rainfall from 1957 to 2018, and the values of the forecast factors in 2025 and 2035 are used as the input to forecast the rainfall in 2025 and 2035. Based on the values of the rainfall, the characteristics of wet and dry seasons are determined.

The prediction and simulation results of the model are analyzed, and 20% of the relative error is used as the criterion. The model of wolf swarm algorithm is constructed by using 24 solar terms, lunar calendar date, sunspot relative number and lunar declination angle as the prediction factors. The training performance of the model is analyzed in Figure 1 and Figure 3, and the fitting effect of the model is good, and the relative error between the simulated value and the measured value is less than 20%. According to the analysis of the prediction performance of the model in Figure 2 and Figure 4, it can be seen that there is a certain deviation between the predicted value and the measured value of the model.The relative deviation between the predicted value and the measured value is less than 20%. It can be seen that the model has good simulation and forecasting ability, and can forecast the future rainfall based on the forecast factors, and then determine the full year rainfall.

4.1.3 Rainfall forecast of Yulin City in 2025 and 2035

Based on the prediction products of SEPC solar cycle, the sunspot relative number in 2025 and 2035 is obtained. The declination angle of the moon in 2025 and 2035 is calculated by using pyephem, an astronomical calculation toolkit in Python. The 24 solar terms lunar dates in 2025 and 2035 are obtained by combining with the astronomical calendar issued by Zijinshan Observatory of China. The prediction factors are input into the model to forecast the rainfall in 2035. The operation model shows that the forecast value of rainfall in 2025 is 386.3mm, which is a normal year. The forecast value of rainfall in 2035 is 529.25 mm, which is a wet year.

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4.2 Calculation of ecological water demand in Yulin area

Based on the predicted wet and dry values, the ecological water supply in 2025 and 2035 is shown in Table 2. It can be seen that the ecological water demand in 2025 is the same as that before the forecast, while the ecological water demand in 2035 is less than 4.095 million m^3, which can use more water resources for industrial production and agricultural irrigation.

4.3 optimal allocation of mine water in Yuheng area

4.3.1 Supply and demand balance analysis

According to the current annual available water supply and annual water demand of each level in Yuheng mining area, the balance of supply and demand is analyzed. The results before rainfall forecast show that in 2025 level year, the mine water supply is 72.84 million m^3, and the water shortage is 17.015 million m^3. In 2035, the mine water supply is 72.84 million m^3, and the water shortage is 12.995 million m^3. The results show that: in 2025, the mine water supply is 72.84 million m^3, and the water shortage is 17.015 million m^3. In 2035, the mine water supply is 72.84 million m^3, and the water shortage is 8.9 million m^3. Therefore, the use of mine water for water supply in Yuheng mining area can effectively alleviate the pressure of regional water supply, and the water shortage in Yuheng mining area is serious. Due to the large number of water sources and different water supply households, in order to maximize the benefit of water supply, it is necessary to optimize the allocation of water resources.

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4.3.2 Optimize configuration

(1) Related parameters

1) Priority determination

Based on the formula in reference [15], the order coefficient of water supply source in Yuheng mining area is: conventional water (1/3) 0.33, mine water (2/3) 0.67. According to the principle of fairness, according to the principle of "ensuring ecological water first, and then meeting agricultural irrigation water and industrial production water", the order of water supply for each user is determined as follows: ecological water, irrigation water and industrial water. The fairness coefficients of each user are calculated as: (3/6) 0.5, (2/6) 0.33, (1/6) 0.17.

2) Determination of cost coefficient

Based on the actual situation of Yulin city where Yuheng mining area is located, industrial, ecological and irrigation water is uniformly allocated by water supply group to mine water and conventional water, so the cost and benefit of conventional water and mine water are equal. Based on the national water fee online query system, according to the current annual water fee collection standard of Yuheng mining area, the industrial and domestic water fees are equal. Based on this calculation, the industrial water fee is 5.55 yuan/m^3, the ecological water fee is 5.55 yuan/m^3, and the irrigation water fee is 0.361 yuan/m^3.

3) Determination of benefit coefficient

Based on the reference [16] in 2007, the benefit coefficient of industrial and ecological water use in Xi'an is 11.94 yuan/m^3, and the benefit coefficient of agricultural water use is 7.02 yuan/m^3. By the data of water resources bulletin of Shaanxi Province, it can be seen that the water consumption per 10000 yuan of industrial added value in Shaanxi Province in 2007 was 46m^3, so the benefit coefficient of industrial water use was 10.2 yuan/m^3. On the base of the research of literature [17], the multi-year average value of irrigation water benefit sharing coefficient in Shaanxi Province is 0.34, and the single square water benefit in 2007 is 3.76 yuan, so the agricultural water benefit coefficient is 1.3 yuan/m^3. It can be seen that the benefit coefficient of industrial and ecological water use in Xi'an is reasonable, while the benefit coefficient of agricultural water use is relatively large. In this paper, the benefit coefficient of agricultural water use in Xi'an is 1.3 yuan / m^3.

According to the above method, based on the current year calculation, the GDP of various industries in Xi'an City in 2007 is converted to the index value of Xi'an City in 2019 in proportion. At the same time, based on the GDP of various industries in Xi'an city and Yulin City in 2019, the industrial water use efficiency coefficient of Yulin City in 2019 is converted. Therefore, the benefit coefficient of irrigation water in Yuheng mining area is 3.7 yuan / m^3, the benefit coefficient of industrial water is 37 yuan / m^3, and the benefit coefficient of ecological water is 63 yuan / m^3.

The parameters related to the optimal allocation of water resources in Yuheng mining area are shown in Table 3.

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(2) Water resources allocation based on rainfall forecast

Based on the planning of water supply source and the development and utilization degree of current water resources in Yuheng mining area, according to the listed objective functions and constraints, the programming simulation calculation can be carried out, and the optimal allocation results and supply and demand balance analysis of each planning level year can be obtained, as shown in Table 4.

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Please insert Table4 here

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It can be seen from the results of optimal allocation of water resources that: before the forecast, in the 2025 planning level year, there will be a water shortage of 17.015 million m^3. After the optimal allocation of water resources, the ecological and industrial sectors will reach the balance of supply and demand and meet the water demand. Agricultural irrigation is short of water. Mine water has achieved priority to meet the ecological, because the maximum benefit priority to meet the industrial, agricultural irrigation using conventional water resources. In the planning level year 2035, the water shortage is 12.995 million m^3. Through the optimal allocation of water resources, both ecology and industry have reached the balance of supply and demand to meet the water demand. Agricultural irrigation is short of water. After the forecast, it will remain unchanged in 2025, and the water shortage will decrease by 4.095 million m^3 in 2035. Rainfall forecast can further meet the agricultural irrigation water demand. The optimal allocation of mine water makes the mine water achieve the priority to meet the ecological needs. Due to the maximum benefit, the priority to meet the industrial needs, the conventional water resources are used for agricultural irrigation.

Since the objective function of this water distribution is the weighted sum of economic benefit and social benefit, and the annual water supply of each planning level is less than the water consumption, priority should be given to the water sources with high water consumption level, and the water sources of each level should be fully utilized to reduce the surplus. The results show that mine water and conventional water are preferentially used in industries with high benefits, which indicates that the allocation result is reasonable and meets the goal of maximum comprehensive benefits of water distribution. In order to further improve the economic and social benefits, we can further reduce the agricultural water demand by improving the agricultural irrigation level.

5 Discussion

(1) The long-term forecast result has a long forecast period, the factor mechanism is not clear, and the forecast result has certain uncertainty. Based on the results of rainfall forecast, it is necessary to make real-time adjustment and analysis according to the weather forecast results and the actual rainfall situation. This method has a good guiding significance for long-term planning.

(2) The water supply model based on multi-source and multi-user can optimize the allocation of water resources with the maximum comprehensive benefit, which can effectively improve the utilization efficiency of water resources. In practical work, it needs to be further adjusted and improved combined with regional policies.

6 Conclusion

The water supply of Yuheng mining area is less than the water demand, so it is necessary to optimize the allocation of water resources to improve the utilization rate of water resources. Through analysis, the water sources of Yuheng mining area are surface water (conventional water), reclaimed water and mine water, and the water users can be divided into industry, ecology and irrigation.

1) Yuheng mining area is an ecologically fragile area with drought and water shortage. If the ecological water demand is calculated based on quota, there will be a large deviation between the ecological water demand and the actual demand. Therefore, in order to ensure the development of the region and reduce the waste of water resources, it is necessary to combine the long-term rainfall forecast to realize

the hierarchical calculation of ecological water demand. Combined with the analysis of supply and demand balance, the optimal allocation of regional water resources is carried out to maximize the comprehensive benefits of water resources.

2) The previous allocation model was based on the qualitative allocation principle of the region. The water quantity of water source allocation was only the feasible solution, not the optimal solution, and the model had the error of supply and demand balance analysis. Therefore, this study built a multi-source and multi-user water resources optimal allocation model based on ecological restoration, mine water and reclaimed water are used for supply. Industrial water can also be guaranteed. Due to the low benefit of irrigation water, it can not be fully guaranteed in the allocation process, resulting in a large gap of agricultural water. In order to ensure the agricultural water use in 2025 and 2035, measures can be taken to save water and increase water supply to reduce agricultural losses. The optimal allocation of water resources based on rainfall forecast can allocate the surplus ecological water demand to agricultural irrigation, so as to improve the utilization efficiency of water resources and provide important support for improving agricultural output.

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Disclosure

No potential conflict of interest was reported by the authors.

Ethical Approval

Not applicable.

Consent to Participate

Not applicable.

Consent to Publish

Not applicable.

Authors Contributions

Not applicable.

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Competing Interests

Not applicable.

Availability of data and materials

The authors confirm that all data supporting the findings of this study are available from the corresponding author by request.

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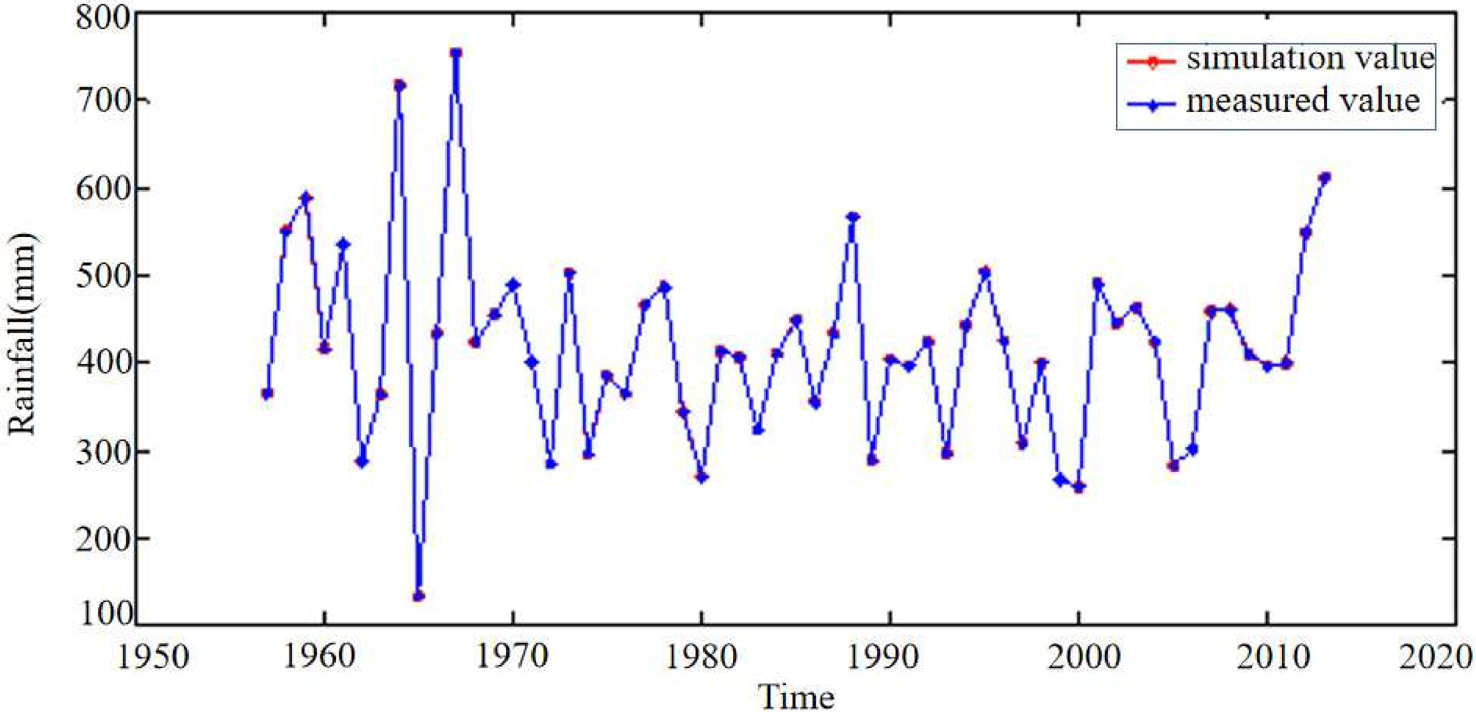

Figure 1

Simulation and measurement of wolf swarm algorithm neural network model 1957-2013

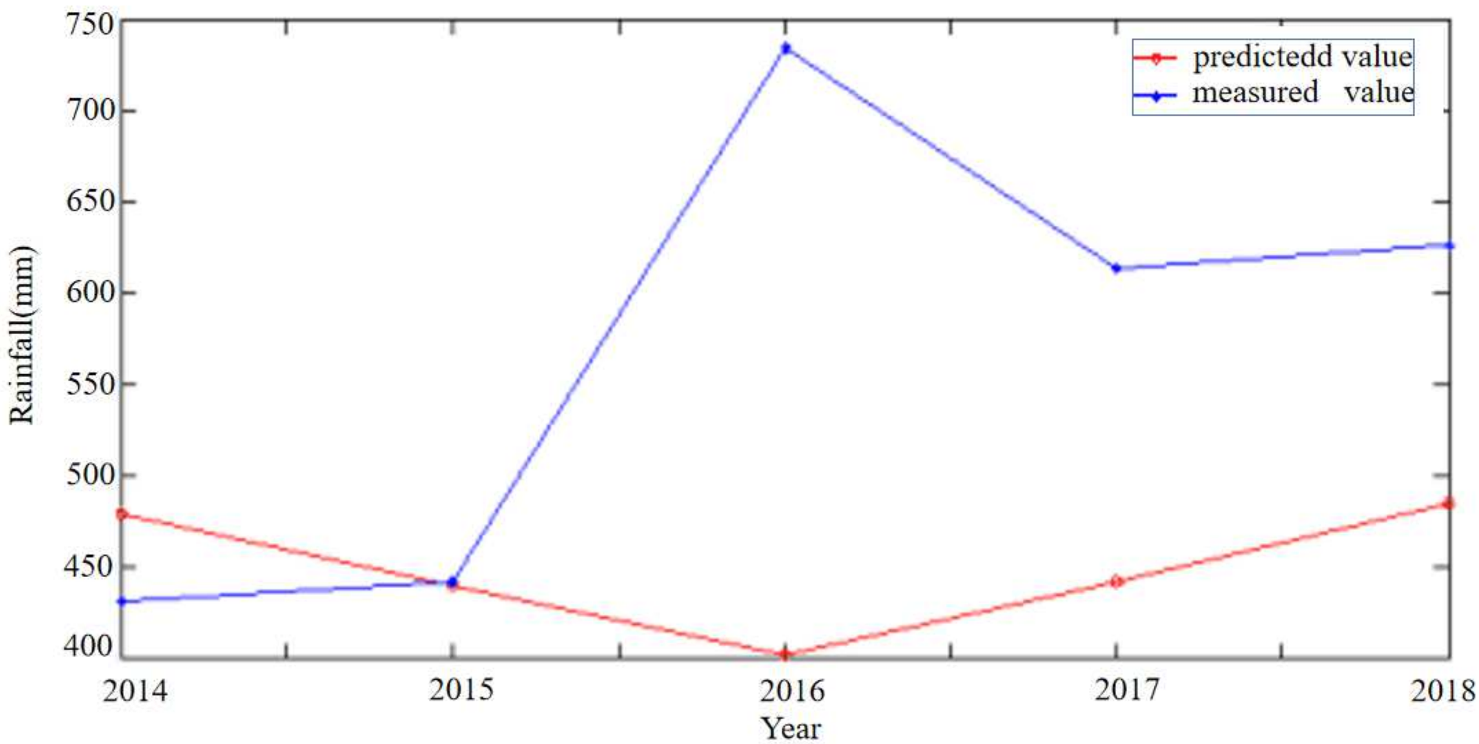

Figure 2

predicted and measured values of wolf colony algorithm neural network model from 2014 to 2018

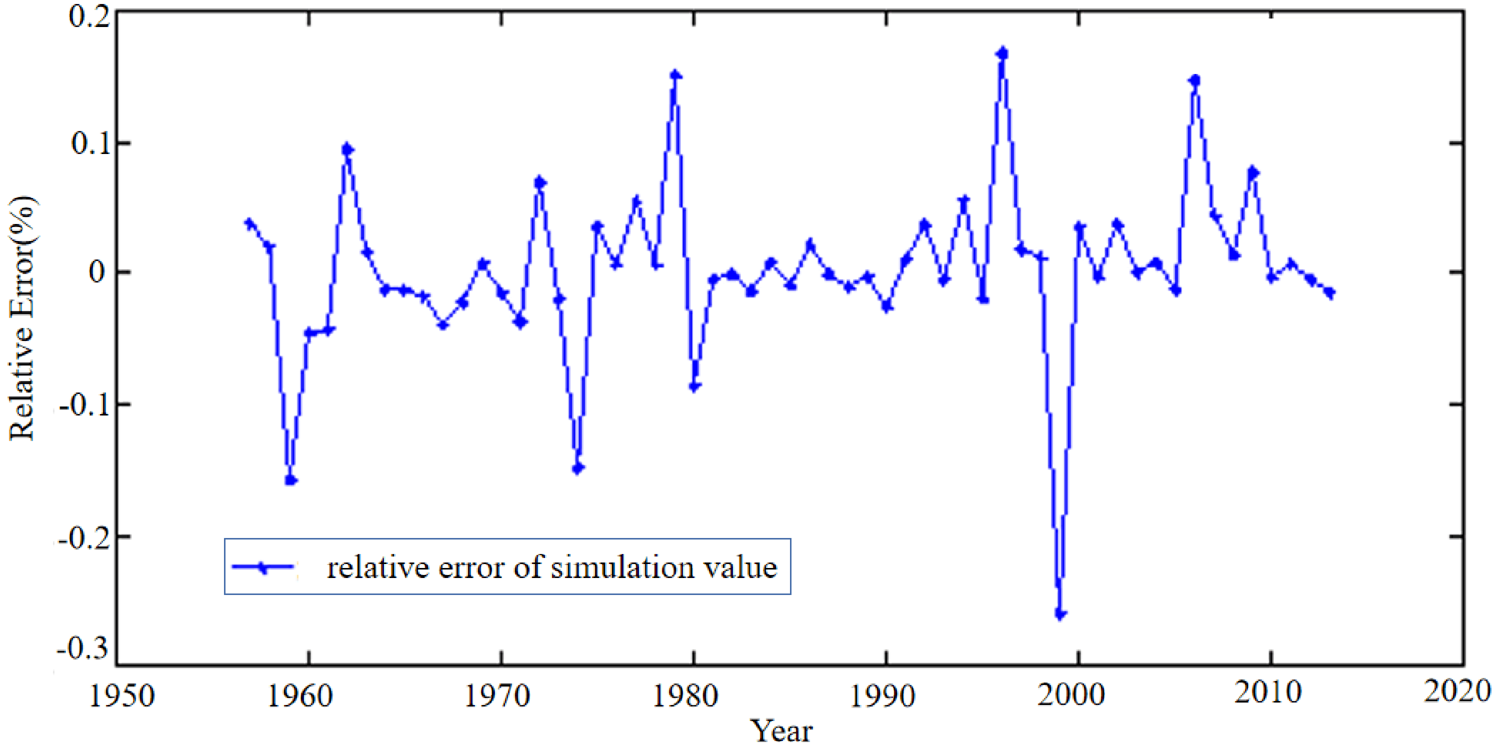

Figure 3

relative error of measured and simulated values of wolf colony algorithm neural network model from 1957 to 2013

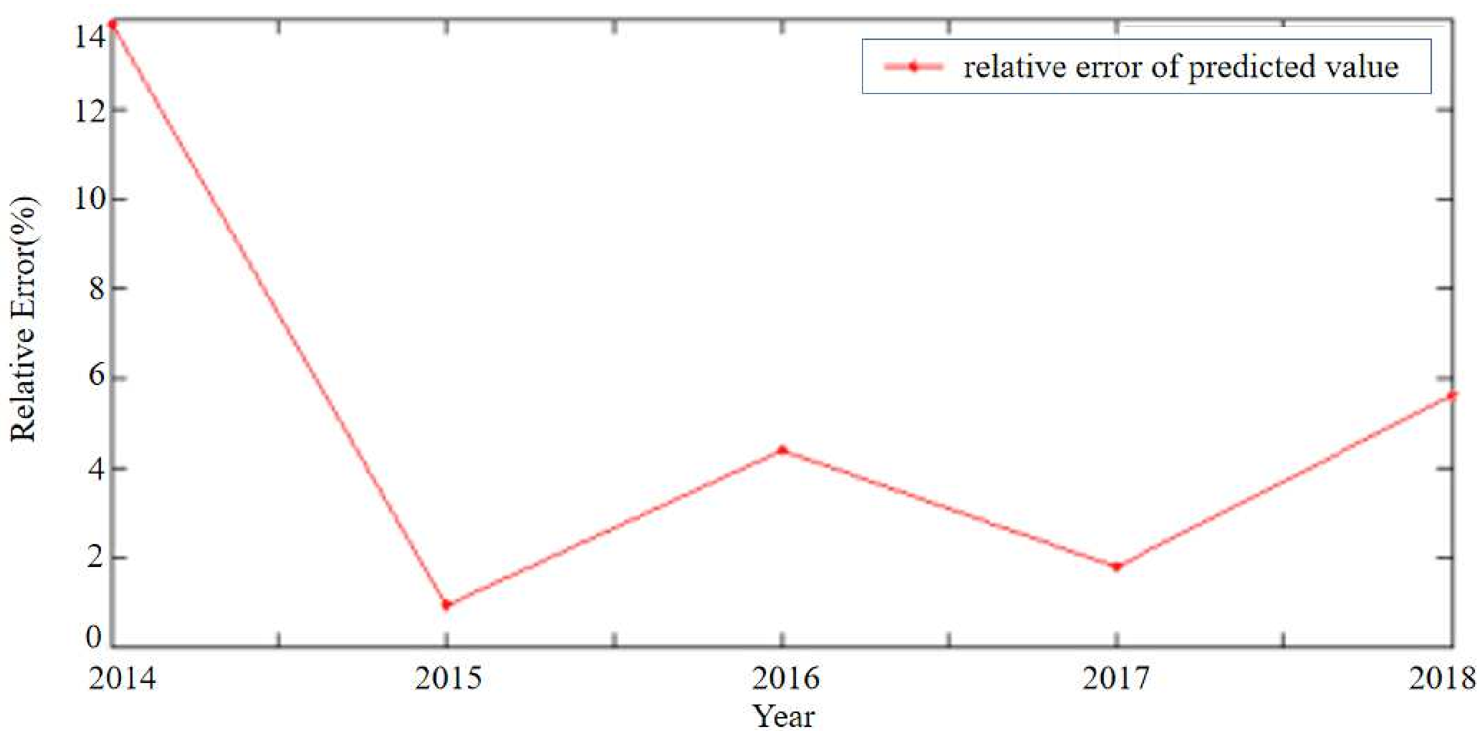

Figure 4

relative error between measured value and predicted value of wolf colony algorithm neural network model from 2014 to 2018