Study on Establishing Early Warning Model of Soil Salinization Disaster

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Abstract. This paper introduced the selection of evaluation factors of soil salinization hazard warning model and the calculation of weight of various factors. We used the fuzzy optimal BP neural model to predict the development degree of future soil salinization, which can effectively reduce the impact on soil salinization disasters.

1. Introduction

Soil salinization is an adverse consequence of the reverse succession of the ecological environment, and continuous succession will become a natural disaster. This kind of disaster causes the accumulation of soil salinity, which leads to the decline of soil fertility, resulting in crop reduction or no crop yield and soil degradation and surface cracking, and the complexity or loss of land and vegetation complexity, causing irreversible losses to the sustainable development of agriculture and economy. Due to unreasonable diversion of yellow water and the abuse of land resources, the groundwater level in the irrigation area is rising, resulting in a large accumulation of soil salinity. The ecological deterioration caused by the increase in soil salinization affects the development of local agriculture and economy to a certain extent, and also imposes a burden on the stability of the ecological environment. In order to alleviate the losses caused by soil salinization disasters, this paper uses fuzzy optimization BP neural network evaluation model to establish a soil salinization disaster warning model to warn the future soil salinization deterioration degree.

Before a disaster or a catastrophe and other dangers that need to be guarded, to send an emergency signal to the relevant department and report the dangerous situation according to the rules summarized in the past or the precursors of the observations, so as to avoid the hazard from being uninformed or under-prepared, thereby minimizing the damage caused by hazards, defined as “early warning”[1]. According to the field investigation of the previous hydrological situation, this paper divides the soil salinization disasters in the Yellow River Delta irrigation area into four categories: no alarm, light alarm, medium alarm and heavy alarm. Different measures were taken for different areas of the irrigation area to reduce the deterioration of soil salinity.

2. Selection of model evaluation factors

The selection of evaluation factors of early warning model of soil salinization disasters cannot be selected at random. It should follow certain principles, such as the principle of combining scientific and data accessibility, the principle of combining qualitative and quantitative, systematic and hierarchical principles, leading and the principle of mutual independence, etc.
Based on the investigation and comprehensive analysis of the current situation of soil salinization in the Yellow River Delta irrigation area, following the above selection principles, we select 9 early warning factors and 8 sample points as the evaluation index from the three aspects of natural geographical factors, soil internal factors and human activities affect, and establish the early warning index system of soil salinization disaster in the study area (see Table 1).

Table 1. Early warning and evaluation indicators for soil salinization disasters.

| Target Layer X | Criterion Layer Y | Indicator Layer Z          |
|----------------|-------------------|---------------------------|
| Natural Geographical Factor Y₁ | Potential Evaporation Z₁ |
|                  | Groundwater Level Z₂ |
|                  | Groundwater Salinity Z₃ |
| Soil Salinization Warning Evaluation Indicator | Slope Value Z₄ |
| Soil Internal Factors Y₂ | PH Z₅ |
|                  | Soil Conductivity Z₆ |
|                  | TDS Z₇ |
|                  | Soil Salt Quantity Z₈ |
| Human Activities Affect Y₃ | Land Use Type Z₉ |

3. Standardization of index system

Before determining the weight, we first need to determine the type of the indicator. Since the indicators are different in dimension and order of magnitude, it is necessary to standardize the indicators. The specific calculation formula is as follows:

For positive benefit indicators, the larger the indicator value indicates the smaller the degree of soil salinization. The formula of the extremely poor standardization method is:

\[ y_{ij} = \frac{x_{ij} - \min \{x_{ij}\}}{\max \{x_{ij}\} - \min \{x_{ij}\}} \] (1)

For negative benefit indicators, the larger the indicator value indicates the more serious the degree of soil salinization. The formula of the extremely poor standardization method is:

\[ y_{ij} = \frac{\max \{x_{ij}\} - x_{ij}}{\max \{x_{ij}\} - \min \{x_{ij}\}} \] (2)

It can be clearly seen from the formula that \( y_{ij} \in [0,1] \) and the higher the \( y \) value, the lower the warning degree of soil salinization; where \( \max \{x_{ij}\} \) is the maximum value of \( X \) for the \( j \)th indicator, and \( \min \{x_{ij}\} \) is the minimum value of \( X \) for the \( j \)th indicator( \( i = 1,2, \cdots, m; j = 1,2, \cdots, n \) ).

4. Weight calculation of early warning factors

In order to distinguish the difference between different indexes on salinization, the fuzzy evaluation method is used to determine the weight value of each index. We use the solution of factor weight of basic unit system to solve another weight, which provides a basis for early warning of soil salinization. The formula for calculating the weight is:

\[ \omega_i = \frac{1 - g_{1i}}{\sum_{i=1}^{s} \frac{1 - g_{1i}}{g_{1i}}}^{1/2}, \quad 0 \leq g_{1i} \leq 1 \] (3)

The results calculated according to formula (3) are shown in Table 2. It can be seen from the results that the weight value of the early warning evaluation index of soil salinization disaster is relatively reliable. The early warning factors are divided according to their weight: soil salinity > potential evapotranspiration > land use type > conductivity > groundwater level > groundwater salinity > TDS > slope value > PH value.
Table 2. Weight calculation result table.

| Early Warning Factor         | Z  | Y(1)     | Y(2)     | Y(3)     | Wi  | Ranking |
|------------------------------|----|----------|----------|----------|-----|---------|
| Potential Evapotranspiration | Z1 | 0.4094   |          | 0.1754   | 2   |         |
| Groundwater Salinity         | Z2 | 0.2047   |          | 0.0877   | 6   |         |
| Groundwater Level            | Z3 | 0.2895   |          | 0.1241   | 5   |         |
| Slope Value                  | Z4 | 0.0965   |          | 0.0414   | 8   |         |
| PH Value                     | Z5 |          | 0.0586   |          | 9   |         |
| Conductivity                 | Z6 |          | 0.3202   |          | 4   |         |
| TDS                          | Z7 |          | 0.1705   |          | 7   |         |
| Soil Salinity                | Z8 |          | 0.4508   |          | 1   |         |
| Land Use Type                | Z9 |          | 1        | 0.1429   | 3   |         |

5. Establishment of salinization disaster assessment model

The fuzzy-preferred BP neural network evaluation model inputs the normalized matrix S of the historical observation index data of the Yellow River Delta irrigation area into the input layer of the model, so that \( u_{ij} = s_{ih} \). The network output value \( u_{ij} \) and the expected output value \( M(u_{ij}) \) correspond to different learning samples respectively. The purpose of this step is to minimize the error between the comprehensive level relative membership degree \( e_h \) of the learning samples.

Assuming

\[
E = \frac{1}{2n} \sum_{j=1}^{2n} E_j = \frac{1}{2n} \sum_{j=1}^{2n} \left[ u_{ij} - M\left(u_{ij}\right) \right]^2
\]  

(4)

Therefore, the objective function of the training is expressed as

\[
M_{nn}E = M_{nn} \left( \frac{1}{2n} \sum_{j=1}^{2n} \left[ u_{ij} - M\left(u_{ij}\right) \right]^2 \right)
\]

(5)

At the end of the training, the new sample matrix X is standardized to obtain the target eigenvalue matrix:

\[
R = \left( r_{ij} \right), \quad i = 1, 2, \ldots, m; \quad j = 1, 2, \ldots, n
\]

(6)

Then input \( r \) into the network, and get the actual output value \( UPJ \) of the neural network, that is, the prediction and evaluation result of the new sample. Calculate the level characteristic value of the evaluation sample according to the following formula:

\[
h_j = c - u_{kj} \left( c - 1 \right)
\]

(7)

The specific steps of the forecast are as follows:

1. Let \( t=1 \) and give \( \alpha \in (0,1) \), \( \eta \in (0,1) \), and \( w_k(t) = w_k(0) \). The convergence of the fuzzy-preferred neural network is used as a criterion.

2. Enter the data into the evaluation sample. Calculate the actual output value of the neural network of the sample.

3. Calculate the average error \( E \) of the network.

4. If \( E \leq \xi \) (where \( \xi \) is the network training accuracy), the training ends, and the process proceeds to step (7); otherwise, it proceeds to the next step.

5. Let \( t=t+1 \), calculate the actual output value of the sample according to the new weight and the index value of each sample, and then calculate the average error \( E \) of the network.

6. Go to step (4).

7. The training is over. Enter a new sample to be calculated and predict the warning level of the sample based on the network output. The specific calculation results are shown in Table 3.
Table 3. Sample forecast results and error test.

| Sample Number | Predicted Value | Actual Value | Original Warning Level | Absolute Error | Relative Error/% | Final Warning Level |
|---------------|-----------------|--------------|------------------------|----------------|------------------|--------------------|
| 1             | 0.5437          | 0.511        | No Alarm               | 0.033          | 6.40             | no Alarm           |
| 2             | 0.5919          | 0.584        | No Alarm               | 0.008          | 1.35             | no Alarm           |
| 3             | 0.7105          | 0.671        | Light Alarm            | 0.040          | 5.89             | middle Alarm       |
| 4             | 0.6531          | 0.635        | Light Alarm            | 0.018          | 2.85             | light Alarm        |
| 5             | 0.8017          | 0.791        | Middle Alarm           | 0.011          | 1.35             | middle Alarm       |
| 6             | 0.7960          | 0.818        | Middle Alarm           | 0.022          | 2.69             | middle Alarm       |
| 7             | 0.8923          | 0.902        | Heavy Alarm            | 0.010          | 1.32             | heavy Alarm        |
| 8             | 0.9815          | 0.987        | Heavy Alarm            | 0.005          | 0.23             | heavy Alarm        |

6. Conclusion
The fuzzy optimization BP neural network evaluation model selected in this paper has a structure of 3 layers. The topology ratio is 9:5:2, the training rate is 0.1, the average absolute error of the sample data is 0.021, the root mean square error is 0.026, and the relative error is 2.3%. The error results are small, indicating that network learning and training are ideal. The maximum absolute error of the test sample is 0.06, the minimum absolute error is 0.004, the average absolute error is 0.024, the maximum relative error is 6.4%, the minimum relative error is 0.23%, and the average relative error is 3.1%. It can be seen from the table that the overall warning level of the Yellow River Delta irrigation area is relatively light, and the proportion of heavy police is small. In the forecast of 8 test sample warning levels, a sample early warning level is falsely reported.

It can be seen that the fuzzy optimization BP neural model can predict the development degree of soil salinization in the future, and can effectively reduce the impact of soil salinization disaster.

References
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