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STUDY ON SUITABILITY ASSESSMENT METHOD OF VEGETATION RESTORATION SPECIES IN DISTURBED SITES OF TRANSMISSION LINE ENGINEERING CONSTRUCTION

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Highlights:
- an index system for evaluating the adaptability is established;
- determine the subjective weight of evaluation index;
- determine the objective weight of evaluation index;
- fuse subjective weight and objective weight to get the final evaluation index weight;
- calculate the certainty of each index.

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Abstract. Screening species that can adapt to the disturbed habitats resulting from transmission line construction is of great practical significance for the ecological restoration of primary vegetation degradation caused by such construction. Therefore, a suitability evaluation method for vegetation restoration species in disturbed areas of transmission line engineering construction is studied to improve the ecological restoration. Based on the principles of stability and durability, adapting to local conditions and trees, and comprehensive and dominant screening, an index system for evaluating the adaptability of vegetation restoration species is established. Determine the subjective weight of evaluation index by G1 method and G2 method. The objective weight of evaluation index is determined by improving entropy weight method and deviation method. Through the optimal combination weighting method, the final evaluation index weight is obtained by combining subjective weight and objective weight. Using cloud model combined with index weight to calculate the certainty of each index. According to the principle of maximum certainty, the evaluation grade corresponding to the maximum certainty is selected as the final suitability evaluation result. The experiments have demonstrated that the suitability evaluation index system of this method exhibits high reliability, and it can effectively determine the weights of the suitability evaluation indices and complete the suitability assessment for vegetation restoration species. Among these species, Elymus chinensis, Panicum miliaceum, Brassica napus, arugula, and rye exhibit the most promising ecological restoration effects.

Keywords: adaptability evaluation index system, G1 method, G2 method, cloud model, index weight, principle of maximum certainty, evaluation grade.

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1. Introduction

The eastern part of Inner Mongolia is referred to as "Mengdong area" for short, encompassing a total area of 665,000 square kilometers, which constitutes 56.2% of the total area of Inner Mongolia (Bai et al., 2021). The Mengdong region is located in an ecotone with complex terrain, variable climate, and uneven rainfall distribution. The north and southwest of the Mengdong area are covered with forest and sandy land, respectively, forming a composite ecosystem of agriculture, forest, animal husbandry, and sandy land (Gong et al., 2022). This region represents a typical ecologically fragile area in northern China. The anthropogenic pressure in recent years has exacerbated its ecological vulnerability (Urrutia-Cordero et al., 2022). During the construction of power transmission lines, the natural ecological environment along areas such as tower foundations and construction roads is under great pressure, especially in ecologically fragile areas in eastern Mongolia. This can easily lead to landscape fragmentation, vegetation destruction, soil structure changes, and soil erosion (Choudhury et al., 2022). Therefore, it is necessary to carry out the research on species adaptability evaluation of vegetation restoration in this area (Wang et al., 2022). The utilization of plants for sand fixation has a long-standing history as a sand-prevention measure.

Lawal et al. (2021) will use NDVI calculated by optical satellites and VOD calculated by passive microwave remote sensing products as indicators for evaluating the suitability of vegetation restoration species, where NDVI stands for the normalized difference vegetation index, which is a vegetation index obtained by satellite remote sensing technology and uses the reflectance difference between near-infrared and red light bands to quantify vegetation coverage and health status. VOD, which represents the optical depth of vegetation, is another vegetation index obtained using passive microwave remote sensing technology, which is mainly used to measure the water content and biomass of the vegetation canopy. Using the fuzzy comprehensive evaluation method, the scores of each evaluation index are calculated to complete the suitability evaluation of the vegetation restoration species. The results show that VOD and NDVI have similar spatial distribution characteristics, and the responses of NDVI and VOD has similar spatial distribution characteristics. However, the amplitude of the NDVI response is generally weak, and the amplitude of the VOD response is also weak. The response of VOD is the weakest at all time scales, although its size changes significantly every year. Comprehensive analysis has shown that the adaptability of vegetation restoration species in this area is poor (Lawal, 2021). Although the method is simple and easy to operate, it is significantly influenced by the selected indicators and subjective factors.

Silva et al. (2021) used the medium resolution image spectral radiometer sensor to obtain 8-year EVI data, evaluated the suitability of vegetation restoration species by enhancing the temporal characteristics of vegetation index (EVI), and combined with the use of seasonal autoregressive integrated moving average (SARIMA) model to evaluate the spectral time patterns of vegetation restoration species under different management modes and design future scenarios. The residual autocorrelation test was carried out for each species model of vegetation restoration and classified according to the information criterion. The accuracy of the SARIMA model was evaluated using a prediction error measure and consistency index. We conclude that the SARIMA model can establish reliable spectral characteristics for vegetation restoration species, which is helpful in determining the management model of vegetation restoration species. This method can effectively evaluate the suitability of vegetation restoration species, identity early signs of dysplasia of vegetation restoration species, and thus reduce the risk of economic loss in the commercial chain (Silva et al., 2021). However, this method cannot fully explain the reasoning process and reasoning basis in detail and a large amount of data is needed to ensure the accuracy of the results.

Carrubba et al. (2022) in the semi-arid Mediterranean region, land resources are often scarce. Therefore, adopting low-shed farming systems may be a sustainable choice for planting vegetation restoration species. In order to evaluate the suitability of vegetation restoration species in the Mediterranean environment, three types of vegetation restoration species ("Cascade", "Chinook" and "Nugget") were planted in 2018 and 2019, and their development speed was evaluated, which was related to the cone, root and biomass yield of plants. In addition, organic (pine bark chips) and synthetic (black polyethylene plastic film) mulches were applied to the same variety, and their comprehensive adaptability was evaluated. The results showed that the faster the growth in the first two stages of plant elongation (up to 50% of the top silk height), the lower the cone yield and total exogenous biomass. The faster the growth rate, the higher the biomass yield of the lower part of the plant. Mulching can significantly affect the growth suitability of vegetation restoration species. The use of synthetic mulch can improve the growth suitability of species used for vegetation restoration. The analysis results show that in the semi-arid Mediterranean environment, the suitability of vegetation restoration species types for low-shed farming systems is very different (Carrubba et al., 2022). However, this method cannot comprehensively evaluate the suitability of vegetation restoration in the species restoration process. The adaptability assessment of vegetation restoration species is random, fuzzy, and uncertain, but the above methods do not consider the influence of fuzziness and randomness simultaneously, and the evaluation results are inconsistent with the facts and the accuracy is not high.

Based on the above research methods, this paper puts forward research on the suitability evaluation method of vegetation restoration species in disturbed land of transmission line engineering construction. As an effective tool to deal with uncertainty, cloud model has been widely used in ecological assessment, environmental management and other fields in recent years. Cloud model can fully describe the uncertainty and fuzziness of evaluation indicators by introducing three digital features of expectation, entropy and super-entropy, which makes the evaluation results more in line with the actual situation. In the evaluation of species suitability for vegetation restoration, the cloud model comprehensively considers multiple ecological factors, calculates the certainty of each index by establishing the cloud model of each factor, and then selects the most suitable species according to the principle of maximum certainty. In the suitability evaluation of vegetation restoration species in disturbed areas of transmission line engineering construction, the importance of ecological factors, the availability of data and the convenience of evaluation are comprehensively considered, and the most suitable weight determination method is selected. The cloud model of each index is established by using the cloud model, and the certainty degree of each index is calculated. When determining the index weight, the importance of ecological factors, the availability of data and the convenience of evaluation are comprehensively considered, and the appropriate weight determination method is selected. According to the principle of maximum certainty, the evaluation grade corresponding to the maximum certainty is selected as the final suitability evaluation result. The cloud model theory fully considers the fuzziness and randomness of evaluation indexes and data and improves the accuracy of species suitability evaluation for vegetation restoration. Therefore, based on the theory of cloud model, suitability is evaluated, which can provide a reference for making suitable species selection schemes and improving the vegetation restoration effect in disturbed areas of transmission line engineering construction. The innovation of this method is as follows:

(1) Based on the principles of stability and durability, adaptation to local conditions and trees, and comprehensive and dominant screening, an index system for evaluating the adaptability of vegetation restoration species is established;

(2) Determine the subjective weight of the evaluation index using methods G1 and G2;

(3) Use the improved entropy weight and deviation methods to determine the objective weight of the evaluation index;

(4) The optimal combination weighting method is used to fuse the subjective and objective weights to obtain the final evaluation index weight;

(5) Use the cloud model combined with index weights to calculate the certainty of each index;

(6) According to the principle of maximum certainty, the evaluation grade corresponding to the maximum certainty is selected as the final suitability evaluation result.

This method is highly reliable for establishing a suitability evaluation index system and can effectively calculate the weight of the suitability evaluation index to evaluate the suitability of vegetation restoration species.

2. Suitability assessment of vegetation restoration species

2.1. General situation of disturbance track project in transmission line engineering construction

The 500 kV transmission project of the first phase of the Anzhong Guangdong Nuclear Power Plant in Mengdong, located in the T38 tower foundation of Horqin Right Front Banner, serves as the research subject in semi-arid regions. The landform along the line of this project is mainly a low-middle mountain landform, and the natural ground elevation is between 600 and 1200 mm. The project area is situated within the mid-temperate semi-arid continental climate zone (Shi & Hu, 2022), characterized by prolonged cold winters, cool and brief summers, and arid, windy springs. The annual average temperature is 2.7 °C, with an accumulated temperature ≥10 °C (2772 °C). The annual average precipitation is 469.3 mm, with rainfall primarily concentrated from June to September. The annual average evaporation is 1835.5 mm, and the frost-free period extends to 105d (Corray et al., 2024). Figure 1 illustrates the construction disturbance trace of this transmission-line project.

Figure 1. Disturbed land of transmission line construction

In the construction of the transmission line project shown in Figure 1, the reason why the land is disturbed is mainly the direct influence of the construction activity itself on the ground. These construction activities mainly include:

(1) Tower foundation construction: To support a transmission line, it is necessary to build a tower foundation on the ground, which involves excavation, backfilling, concrete pouring, and other processes that directly destroy the original surface vegetation and soil structure.

(2) Line laying: The laying of transmission lines requires dig trenches or erect overhead lines, which will further disturb the surface, destroy vegetation cover, and affect soil stability.

(3) Traffic of construction vehicles and equipment: During the construction period, frequent traffic of heavy vehicles and equipment compacts the soil, changes the physical properties of the soil, and simultaneously causes crushing damage to the vegetation along the way.

(4) Construction of temporary facilities: To support construction activities, it is necessary to build temporary facilities such as sheds, warehouses, and construction roads, which occupy and destroy the original land.

(5) Material stacking and waste disposal: The building materials and waste generated in the construction process must be stacked and disposed. These activities occupy land and cause soil pollution and vegetation damage.

In summary, the land disturbance in the construction of transmission lines is mainly caused by the direct destruction and occupation of the ground by construction activities. This disturbance not only affects the surface vegetation and soil structure, but may also have a long-term impact on the surrounding ecological environment. Therefore, in the construction process, it is necessary to construct a suitability evaluation index system for vegetation restoration species in disturbed areas of transmission line engineering construction to reduce the negative impact of construction on the environment.

2.2. Construction of suitability evaluation index system of vegetation restoration species in disturbed areas of transmission line engineering construction

The species suitability evaluation of vegetation restoration in disturbed areas of transmission line engineering construction, should consider the influence of natural environment such as atmosphere, temperature, sunshine, moisture and soil pH, and determine the adaptation range of each species to these environmental factors. Based on the principles of stability and durability, adapting to local conditions and trees, and comprehensive and dominant screening, combined with the natural environmental conditions in Mengdong area (Adomako & Amankwah-Amoah, 2021), three first-class indicators including general ecological adaptability, windbreak and sand fixation effect and economic management indicators were determined. Based on the primary indicators, five secondary evaluation indicators and nine specific indicators are divided. The index system of species suitability evaluation for vegetation restoration is shown in Table 1.

Table 1. Vegetation restoration species suitability assessment index system

C1	C1-1	C1-1-1
Ecological suitability	Drought tolerance	Transpiration rate
		Water utilization rate
	Biodiversity	Diversity index
	Land suitability	Slope
		Average annual precipitation
		Soil layer thickness
		Soil type
Windproof and sand-fixing effect	Ameliorate soil	Soil water content
		Organic matter
		Total nitrogen
		Total phosphorus content
		Total potassium
Economic management cost	Seedling cost	Seedling cost

The indicators selected for the species suitability assessment of vegetation restoration in disturbed areas of transmission line engineering construction mainly come from field observations, experiments, and local investigations. To facilitate calculation, specific indicators such as transpiration rate, water use efficiency, diversity index, slope, average annual precipitation, soil thickness, soil type, soil water content, soil organic matter, soil total nitrogen, soil total phosphorus, soil total potassium, and seedling cost are standardized using the range standardization method (Houtven et al., 2021).

2.3. Weight calculation of suitability evaluation index of vegetation restoration species in disturbed areas of transmission line engineering construction

The G1 method is employed to determine the subjective weight of species suitability assessment for vegetation restoration in disturbed areas of transmission line engineering construction (Chen & Dai, 2021), and the specific steps are as follows:

Step 1: Determine the sequence relationship of species suitability evaluation indexes of vegetation restoration in disturbed areas of transmission line engineering construction using the G1 method.

Step 2: Experts give a rational assignment of the ratio of index x_{k-1} to x_k importance q_k for the suitability of adjacent vegetation restoration species.

Step 3: If expert gives the rational assignment of the ratio of importance of index x_{k-1} to x_k of the suitability of adjacent vegetation restoration species q_k, then the m G1 method weight of each index w_m is:

$$w_m = \frac{1}{1+\sum_{k=2}^{m}\prod q_k}. \tag{1}$$

Step 4: The weight $w_{k-1} = q_k w_k$ of $m-1,\cdots,3,2$ index is obtained from the weight w_m, among which, w_{k-1} is $k-1$ G1 method weight of each index; q_k is rational assignment gives by experts.

The G2 method is employed to determine the subjective weight of species suitability assessment for vegetation restoration in disturbed areas of transmission line engineering construction (Liu et al., 2022). The specific steps are as follows:

Step 1: Determine the sequence relationship of species suitability evaluation indexes of vegetation restoration in disturbed areas of transmission line engineering construction using the G2 method.

Step 2: The expert gives the least important one and only one indicator, which is recorded as x_m.

Step 3: Experts give a rational assignment of the ratio of other indicators x_k to x_m importance a_k.

Step 4: If the expert gives a_k rational assignment, the vegetation restoration species suitability assessment under the second index k G2 method weight w_k of each index to the secondary index layer:

$$w_k = \frac{a_k}{\sum_{k=2}^{m} a_k}. \tag{2}$$

Among them, w_k is k G2 method weight of each evaluation index; a_k is rational assignment gives by experts; m is the number of evaluation indexes for species suitability of vegetation restoration in disturbed areas of transmission line engineering construction.

The characteristics of methods G1 and G2 reflect the importance of indicators through subjective ranking, wherein significant indicators are assigned greater weight.

The entropy weight method is employed to determine the objective weight of species suitability assessment for vegetation restoration in disturbed areas of transmission line engineering construction. The specific steps are as follows:

Step 1: Quantify the evaluation index of species suitability for vegetation restoration in disturbed areas of transmission line engineering construction and establish a normalized matrix. The index data are quantified as 0–1. The equation is as follows:

$$g_k = \frac{x_k - x_{\min}}{x_{\max} - x_{\min}}. \quad (3)$$

Among them, $x_{\max}$, $x_{\min}$ are the maximum and minimum value of species suitability evaluation index for the same vegetation restoration.

Step 2: Calculate the entropy value of each index H_k, the equation is as follows:

$$\begin{cases} H_k = -\dfrac{\sum_{k=1}^{m} f_k \ln f_k}{\ln m} \\ f_k = \dfrac{1+g_k}{\sum_{k=1}^{m}\left(1+g_k\right)} \end{cases}. \quad (4)$$

Among them, f_k is the proportion of each index g_k.

Step 3: Calculate the entropy weight of each index w_k, the equation is as follows:

$$w_k = \frac{1-H_k}{\sum_{k=1}^{m}\left(1-H_k\right)}. \quad (5)$$

The rank ratio method ranks according to the index evaluation from excellent to poor and can eliminate the interference of some abnormal extreme values by correcting the coefficient, which enables the detection of subtle changes in the index (Li et al., 2022) and is suitable for all kinds of evaluation objects. Based on a comprehensive consideration of the factors influencing species suitability assessment for vegetation restoration in areas disturbed by transmission line engineering construction, each index is assigned according to its degree of influence. The greater the degree of influence on species suitability assessment of vegetation restoration in the disturbed areas of transmission line engineering construction (Saraswat & Digalwar, 2021), the index value is m, slightly better value is $m-1$, the lowest index value is 1. The improved entropy weight method can reduce the subjective and objective influences better. Then, the preference correction coefficient of the assigned index x_k is:

$$R_k = \frac{g_k}{m}. \quad (6)$$

According to the principle of minimum relative information entropy:

$$\min F = \sum_{k=1}^{m} \ln w_k. \quad (7)$$

Using Lagrange multiplication to optimize the above problems, we get:

$$\hat{w}_k = \frac{\dfrac{w_k \cdot R_k}{2}}{\sum_{k=1}^{m}\dfrac{w_k \cdot R_k}{2}}. \quad (8)$$

Using the maximum deviation method, the objective weight of the species suitability assessment of vegetation restoration in disturbed areas of transmission line engineering construction is determined. w_k is the weight for the index k, $w_k \geq 0$. For indicators k, use $\rho_{ik}(w)$ represents the object of evaluation i deviation from the index values of all other appraisees, then:

$$\rho_{ik}(w) = \sum_{k=1}^{m}\left|g_{ij}w_k - g_{ik}w_k\right|. \quad (9)$$

Among them, g_{ij} is the quantified value of the j of the i evaluated object (Davies et al., 2020); g_{ik} is the quantified value of the k th index of the i th evaluated object.

Generally speaking, for index j, the total deviation of all appraisees from other appraisees can be expressed as:

$$\rho_j(w) = \sum_{i=1}^{n}\sum_{k=1}^{m}\rho_{ik}(w), \quad (10)$$

where n is the number of evaluation objects for species suitability for vegetation restoration in disturbed areas of the transmission line engineering construction.

According to the principle of maximum deviation, the optimization model is constructed as follows:

$$\max \rho(w) = \sum_{i=1}^{n}\sum_{k=1}^{m}\rho_{ik}(w)$$
$$s.t. \begin{cases} w_k \geq 0 \\ \sum_{k=1}^{m} w_k^2 = 1. \end{cases} \quad (11)$$

Solve this optimization model and normalize it to get the weight of deviation method:

$$w_k = \frac{\sum_{i=1}^{n}\sum_{k=1}^{m}\left|g_{ij} - g_{ik}\right|}{\sum_{i=1}^{n}\sum_{k=1}^{m}\sum_{j=1}^{m}\left|g_{ij} - g_{ik}\right|}. \quad (12)$$

In the Equation (12) $\sum_{i=1}^{n}\sum_{k=1}^{m}\left|g_{ij} - g_{ik}\right|$ represents all n the evaluated object j the deviation obtained by subtracting the normalized values of each vegetation restoration species suitability evaluation index from each other and then summing the absolute values; $\sum_{i=1}^{n}\sum_{k=1}^{m}\sum_{j=1}^{m}\left|g_{ij}-g_{ik}\right|$ represents all m the sum of the deviations of the indicators.

Equation (12) means that the deviation of the j index accounts for the proportion of the total deviation of all indexes (Basijokaite & Kelleher, 2020), and the greater the proportion, the greater the weight of the index.

Four methodologies–namely, the G1 method, G2 method, improved entropy weight method, and deviation method–are employed to calculate the weight of w_k, respectively. The combination weight is:

$$w=\sum_{l=1}^{L}\beta_l w_l. \quad (13)$$

Among them, β_l represents the combination coefficient; $\sum_{l=1}^{L}\beta_l=1$; $l=1,2,3,4$ represents an empowerment method.

The generalized distance between the weighted score of each evaluation object and the ideal point is the minimum:

$$\min\sum_{i=1}^{n}d_i=\sum_{l=1}^{L}\beta_l w_l^k\left(1-g_k\right). \quad (14)$$

Among them, d_i is the generalized distance between the score and the ideal point for each evaluation object; β_l is the combination coefficient; w_l^k is l method of species empowerment k weight of suitability evaluation indexes of vegetation restoration species.

The advantage of finding the combination weight coefficient using Equation (14) lies in its ability to minimize the generalized distance between the weighted score of each evaluation object and the ideal point, thereby embodying the principle that proximity to the ideal point correlates with a higher score.

Jaynes' maximum entropy principle is introduced to reflect the consistency of each weighting result, and an objective function is established based on the idea of the minimum difference of each weighting result:

$$\max\hat{H}=-\sum_{l=1}^{L}\beta_l\ln\beta_l. \quad (15)$$

The advantages of Equation (15) in determining the combination weight coefficient are as follows: The Jaynes maximum entropy principle is introduced to reflect the consistency of each weighting result, and the combination coefficient is determined based on the idea of maximum consistency of each weighting result. This approach mitigates the issue of individual single weighting methods contributing insufficiently to the combination weight result and eliminates the problem of a single weighting method having no influence on the combination weight.

Considering the generalized distance between the weighted score of each evaluation object and the ideal point, as well as the Jaynes maximum entropy principle, the objective function is established as:

$$\begin{aligned}&\min\lambda\sum_{l=1}^{L}\beta_l w_l^k\left(1-g_k\right)+\left(1-\lambda\right)\sum_{l=1}^{L}\beta_l\ln\beta_l\\&s.t.\quad\sum_{l=1}^{L}\beta_l=1,\end{aligned} \quad (16)$$

where, the parameters $0<\lambda<1$, represents the balance coefficient between two targets.

Constructing Lagrange function to solve combination coefficient β_l, solution:

$$\beta_l=\frac{e^{-\left[1+\lambda\sum_{l=1}^{L}\frac{w_l^k\left(1-g_k\right)}{1-\lambda}\right]}}{\sum_{l=1}^{L}e^{-\left[1+\lambda\sum_{l=1}^{L}\frac{w_l^k\left(1-g_k\right)}{1-\lambda}\right]}}. \quad (17)$$

2.4. Suitability assessment of vegetation restoration species in disturbed sites of transmission line construction based on cloud model

When the growth conditions for vegetation restoration species are adequately met, these species are considered to establish readily, indicating that vegetation restoration is feasible. The suitability of vegetation restoration species is categorized into four grades: most suitable, suitable, moderately suitable, and unsuitable. The results are presented in Table 2.

Table 2. Suitability assessment criteria for vegetation restoration species

Suitability class	Standard
Optimum	The growth and development of species are unlimited, and there is no need for artificial promotion and special measures to restore areas
Suitable	Certain limitations exist regarding the growth and development of vegetation restoration species; however, their impact is minimal, and these species can recover under natural conditions
Basic suitability	The growth and development of vegetation restoration species are limited, and new ecosystems can be built under certain guidance
Indisposition	The growth and development limits of vegetation restoration species are very serious, and there is no possibility of recovery

According to Table 2, the suitability of vegetation restoration species is divided into four clear grades, namely, optimal, suitable, basically suitable, and unsuitable. Based on the above analysis, the following conclusions can be drawn: in the vegetation restoration project, it is necessary to select suitable species according to the specific conditions of the restoration area to ensure the success of the restoration work, and different species have different adaptabilities to the environment, so it is very important to evaluate their suitability for building a stable and sustainable ecosystem. For species in the "basically suitable" level, additional guidance and intervention measures may be needed to support their growth and ecosystem establishment, which may be a great challenge to restore vegetation in these areas for unsuitable species, and to consider alternatives or strengthen other ecological restoration measures.

The cloud model is used to evaluate the suitability of vegetation restoration species in the disturbed land resulting from transmission line engineering construction. This model represents a two-way cognitive approach for qualitative and quantitative transformation, encompassing two fundamental algorithms: forward cloud and reverse cloud. Forward normal cloud algorithm is based on normal distribution and different from normal distribution, which combines qualitative concepts at the same time for Z digital characteristics cloud model $\left(E_x, E_n, H'_e\right)$, in which, E_x is the expectation, this represents the most significant qualitative concept in the field of suitability evaluation for vegetation restoration species in areas disturbed by transmission line engineering construction. The adaptability evaluation index of vegetation restoration species Z is a qualitative concept. Z is a typical sample of concrete quantification; E_n is entropy, which belongs to qualitative concept. Z is the measure of fuzziness is uncertainty. The greater the entropy, the more qualitative it can be. Z is the greater the scope of acceptance; H'_e is super entropy and according to the definition of entropy, superentropy is an uncertainty measure of entropy, which reflects the dispersion degree of cloud droplets and the thickness of clouds. A cloud generator is a cloud model generation algorithm modularized through software implementation or solidified via hardware integration. The forward normal cloud generator evaluates the digital characteristics of the index according to the suitability of the input vegetation restoration species. $\left(E_x, E_n, H'_e\right)$ and the number of cloud droplets N. A cloud picture representing the position of each cloud drop and its certainty in a rectangular coordinate system is generated. The specific steps for employing the cloud model to assess the species suitability for vegetation restoration in areas disturbed by transmission line engineering construction are as follows:

Step 1: According to the definition of normal cloud and the digital characteristics of vegetation restoration species suitability evaluation index corresponding to qualitative concept $\left(E_x, E_n, H'_e\right)$, generate to E_n for expectations, H'^2_e is normal random number with variance $Y_\eta = N\left(E_n, H'^2_e\right)$, $\eta = 2, 3, \cdots, N$.

Step 2: Put Y^2_η as a variance, E_x is the expectation, a normal random number is generated $\chi_\eta = N\left(E_x, Y^2_\eta\right)$ (Hui et al., 2021).

Step 3: Calculate the degree of certainty μ_η, the equation is as follows:

$$\mu_\eta = e^{-\frac{\left(\chi_\eta - E_x\right)^2}{2Y^2_\eta}}. \quad (18)$$

Step 4: Due to the qualitative concept of vegetation restoration species adaptability evaluation index in the cloud model Z the certainty of is not a fixed value, but a probability distribution (Hwang et al., 2023). In order to ensure the reliability of the evaluation results, it is necessary to run the normal cloud generator repeatedly N time, and then take N average certainty obtained by secondary operation $\bar{\mu}$ as a certainty matrix of the elements U.

Step 5: Determine evaluation level. According to the adaptability of vegetation restoration species, the index weight is evaluated w and the i-th is evaluated.

The degree of certainty matrix $Zi = (zjp)n \times P$ of the j-th evaluation index of the object with respect to the evaluation grade is obtained from Equation (18). The comprehensive certainty matrix of the objects i to be evaluated about each evaluation level S:

$$S = wU = \begin{pmatrix} s_1 & s_2 & \cdots & s_v \end{pmatrix}. \quad (19)$$

Among them, s_m is the object to be evaluated about the degree of certainty v of an evaluation level, $s_v = \sum_{k=1}^{m} w_k \bar{\mu}_k$, w_k is k weights of adaptability evaluation indexes of three vegetation restoration species.

According to the principle of maximum certainty, the evaluation grade corresponding to the highest degree of certainty is selected as the final evaluation result for the object to be evaluated.

3. Experimental analysis

This study utilizes the 500 kV transmission project of the first phase of the XingAnZhongGuang Nuclear Power Plant in Mengdong as the research subject. The methodology employed evaluates the suitability of vegetation restoration species in the construction disturbance site of the transmission line project, with the objective of enhancing the vegetation restoration efficacy at the construction disturbance site.

As a sand control measure, plant sand fixation has a long history, and planting suitable ecological restoration species plays an important role in the establishment of short-term populations and formation of long-term ecosystems. In view of the effect of vegetation restoration, combined with local field investigation, the main vegetation restoration species were found out, including tall fescue, elymus dahuricus, sweet clover, astragalus adsurgens, Caragana korshinskii, Populus tomentosa, broomcorn millet, Shapong, Brassica napus, Achnatherum splendens, Lolium perenne, Kentucky Bluegrass in cold region, alfalfa, Artemisia argyi, Lepidium uniflora, etc. Its suitability and the most suitable species for vegetation restoration were evaluated, which laid the foundation for the next step of vegetation restoration. When ecological restoration is carried out, especially for highly targeted projects such as plant sand fixation, the species suitability assessment should be based on a comprehensive and scientific method to ensure that the selected species can successfully establish and play their expected ecological functions in the target environment. In order to enhance the scientificity and rationality of species selection, a comprehensive evaluation method is adopted to quantitatively evaluate the candidate species, which can comprehensively consider multiple ecological factors and give relatively objective evaluation results.

Reliability refers to the consistency or stability of the measurement results. Cronbach's α coefficient was selected to analyze the reliability of the evaluation index system of vegetation restoration species adaptability established by this method using SPSS18.0. The proximity of Cronbach's α coefficient to 1 indicates higher reliability of the evaluation index, and the analysis results are presented in Table 3.

Table 3. Reliability analysis results of vegetation restoration species adaptability assessment index system

Three-level index	Cronbach's α coefficient
Transpiration rate	0.987
Water utilization rate	0.953
Diversity index	0.949
Slope	0.991
Average annual precipitation	0.986
Soil layer thickness	0.978
Soil type	0.955
Soil water content	0.968
Organic matter	0.994
Total nitrogen	0.959
Total phosphorus content	0.972
Total potassium	0.981
Seedling cost	0.937

As shown in Table 3, the Cronbach's α coefficient of each evaluation index approaches 1, indicating high reliability of the suitability evaluation index system for vegetation restoration species in disturbed areas of transmission line engineering construction established by this method. Furthermore, the internal consistency reliability of these evaluation indices is substantial.

The method in this study calculates the weight of the suitability evaluation index of vegetation restoration species in disturbed areas of various transmission line projects. Table 4 presents the calculation results of the evaluation index weights, utilizing tall fescue as an exemplar of vegetation restoration species.

According to Table 4, the method in this study can effectively calculate the weight of the species suitability evaluation index of tall fescue vegetation restoration and provide data support for subsequent species suitability evaluation of vegetation restoration. Experiments demonstrates that the method in this study is feasible for calculating the index weight of species suitability evaluation for vegetation restoration.

Using this method, the suitability of 17 types of vegetation restoration species, such as Festuca arundinacea, Elymus dahuricus, Astragalus mongolicus, Astragalus adsurgens, Caragana korshinskii, Cynanchum Panicum, Achnatherum splendens, Lolium perenne, Kentucky Bluegrass in cold region, Medicago sativa, Artemisia sphaerocephala, Solanum lyratum, arugula and rye, was evaluated.

Table 5. Suitability assessment results of different types of vegetation restoration species

Types of vegetation restoration species	Comprehensive certainty				Evaluation result
	Optimum	Suitable	Basic suitability	Indisposition	
Tall fescue	0.189	0.197	0.215	0.399	Indisposition
Lye grass	0.555	0.099	0.139	0.207	Optimum
Sweet clover	0.216	0.424	0.158	0.202	Suitable
Astragalus sinensis	0.235	0.398	0.196	0.171	Suitable
Caragana caragana	0.233	0.415	0.191	0.161	Suitable

Table 4. Weight calculation results of vegetation restoration species adaptability assessment indicators

Primary index	Weight	Secondary index	Weight	Three-level index	Weight
Ecological suitability	0.28	Drought tolerance	0.35	Transpiration rate	0.48
				Water utilization rate	0.52
		Biodiversity	0.24	Diversity index	1
		Land suitability	0.41	Slope	0.24
				Average annual precipitation	0.18
				Soil layer thickness	0.23
				Soil type	0.35
Windproof and sand-fixing effect	0.39	Ameliorate soil	1	Soil water content	0.18
				Organic matter	0.26
				Total nitrogen	0.15
				Total phosphorus content	0.14
				Total potassium	0.27
Economic management cost	0.33	Seedling cost	1	Seedling cost	1

End of Table 5

Types of vegetation restoration species	Comprehensive certainty				Evaluation result
	Optimum	Suitable	Basic suitability	Indisposition	
Yang Chai	0.174	0.098	0.224	0.504	Indisposition
Proso millet	0.392	0.054	0.319	0.235	Optimum
Chapon	0.327	0.147	0.083	0.443	Indisposition
Rape	0.468	0.209	0.251	0.072	Optimum
Achnatherum splendens	0.134	0.107	0.395	0.364	Basic suitability
Ryegrass	0.203	0.117	0.486	0.194	Basic suitability
Bluegrass cold	0.248	0.093	0.413	0.246	Basic suitability
Alfalfa	0.301	0.335	0.118	0.246	Suitable
Artemisia	0.227	0.196	0.359	0.218	Basic suitability
Eriodictyon japonicum	0.127	0.055	0.403	0.415	Indisposition
Arugula	0.558	0.192	0.218	0.032	Optimum
Rye	0.368	0.147	0.237	0.248	Optimum

According to Table 5, this method is feasible to evaluate the suitability of vegetation restoration species in the disturbed areas of transmission line engineering construction. After evaluation, it is known that the vegetation species with the best ecological restoration effect are Elymus chinensis, Panicum miliaceum, Brassica napus, arugula and rye. The vegetation species with the worst ecological restoration effect are Festuca arundinacea, Populus tomentosa, Shapeng and Lycopodium distichum.

This methodology is employed to evaluate the drought tolerance of Elymus pumila, Panicum miliaceum, Brassica napus, arugula, and rye, which are identified as the most suitable species for vegetation restoration. The drought tolerance of these five species is quantified using transpiration rate measurements. The results of this analysis are presented in Figure 2.

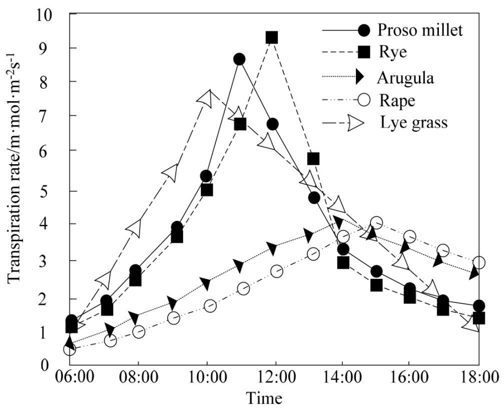

Figure 2. Diurnal variation of transpiration rate of different vegetation

According to Figure 2, the transpiration rates of rye and broomcorn millet are basically the same, and the transpiration rates of arugula and Brassica napus are smaller than those of rye and broomcorn millet. Generally speaking, the transpiration rates of Elymus dahuricus, broomcorn millet, Brassica napus, arugula and rye are all single-peak curves, with larger changes. The transpiration of leaves of Elymus pumila, Panicum miliaceum, Brassica napus, arugula and rye changes with time in one day, which is related to different vegetation types, leaf and individual development age, physiological process and circadian rhythm, and is also affected by external natural ecological environment conditions. Light, temperature and CO2 concentration will all affect the photosynthesis of plants, and these factors will show obvious changes in a day. Therefore, photosynthesis also shows various daily variation laws. The transpiration rate of Elymus chinensis, Panicum miliaceum, Brassica napus, arugula and rye will peak because the water vapor saturation between mesophyll cells of plants will increase with the increase of light intensity and temperature, and decrease with the decrease of light intensity and temperature. The stomatal opening degree of leaves will be reduced or even partially closed, so the peak transpiration rate of arugula is the lowest, followed by Brassica napus, indicating that arugula has the best drought tolerance, that is, the vegetation restoration effect is the best, followed by Brassica napus.

The ecological restoration of the disturbed land in the transmission line project after applying the method in this study is shown in Figure 3.

Figure 3. Ecological restoration of disturbed land in transmission line construction

As shown in Figure 3, after applying the suitability evaluation method of vegetation restoration species in the disturbed land of transmission line engineering construction, the ecological restoration effect of the disturbed land can be significantly improved, dense growth of vegetation can be promoted, and the ecological environment of the entire region can be improved. Through the suitability evaluation method, vegetation restoration species that adapt to the specific environmental conditions of a construction disturbance site can be accurately screened. These species not only have strong resistance and adaptability but can also grow rapidly under harsh soil and hydrological conditions, thus improving the survival rate of vegetation and reducing the failure rate in the restoration process.

4. Conclusions and prospect

4.1. Conclusions

The construction of transmission line engineering significantly disrupts the original natural ecosystem through large-scale quarrying and earthwork filling, resulting in the degradation of native vegetation and increasing the risk of soil erosion. To mitigate the effects on severely degraded construction-disturbed land, ecosystem restoration and reconstruction are essential. Vegetation reconstruction is a crucial step in ecosystem restoration. The establishment of suitable vegetation can mitigate soil erosion risk, facilitate the restoration of soil structure and fertility, and initiate natural succession processes within the ecosystem. Consequently, this study investigates the suitability evaluation method of vegetation restoration species in the construction disturbance site of transmission line engineering, selects suitable vegetation species, enhances the ecological restoration effect of the construction disturbance site, and improves the ecological environment of the construction disturbance site. Through this research, the following conclusions are drawn:

(1) The suitability evaluation index system of vegetation restoration species in disturbed areas of transmission line engineering construction established using this method has high reliability.

(2) The method in this study can effectively calculate the weight of the species suitability evaluation index for vegetation restoration of tall fescue, and it is feasible to calculate the weight of the species suitability evaluation index for vegetation restoration.

(3) After the evaluation of this method, we know that the vegetation species with the best ecological restoration effect are Elymus chinensis, Panicum miliaceum, Brassica napus, arugula and rye; The vegetation species with the worst ecological restoration effect are Festuca arundinacea, Populus tomentosa, Shapeng and Lycopodium distichum.

(4) The lower the transpiration rate, the better the drought tolerance of vegetation, among which the peak transpiration rate of arugula is the lowest, followed by Brassica napus, indicating that arugula has the best drought tolerance, that is, the vegetation restoration effect is the best, followed by Brassica napus.

(5) After applying the method in this study, the ecology of the disturbed land of transmission line engineering construction can be effectively restored, so that the vegetation in the disturbed land grows densely, and the ecological restoration effect in this area can be improved.

4.2. Prospect

Through a systematic evaluation method, managers can scientifically select suitable vegetation restoration species and reduce the waste of resources and ecological damage caused by blind planting. This method provides a scientific basis for the long-term environmental management of transmission line engineering and is helpful for realizing the harmony and unity of engineering construction and ecological environment protection.

The limitations of this study are as follows:

(1) Difficulty in data acquisition: A large amount of ecological and environmental data, including soil conditions, climate characteristics, and vegetation distribution, are needed in the assessment process, so it is difficult to acquire and process the data.

(2) Evaluation complexity: The evaluation method involves many factors and indicators that must be considered comprehensively, which increases the complexity and time consuming of the evaluation.

(3) Regional differences: The ecological environment characteristics of different regions are different, so the assessment methods need to be appropriately adjusted for different regions, which increases the difficulty of universality of the methods.

The future research directions are as follows:

(1) Future research should further refine and improve the assessment system, not only considering the growth characteristics and environmental adaptability of species but also including climate change, soil conditions, hydrological characteristics, biodiversity protection, and other factors to build a more comprehensive and scientific assessment model.

(2) Using modern scientific and technological means, such as remote sensing technology, GIS geographic information systems, and aerial photography of unmanned aerial vehicles, high-precision spatial data and ecological information of the disturbed areas in the construction of transmission lines are obtained. Through big data analysis, accurate assessment of species suitability for vegetation restoration can be achieved.

(3) Deeply study the sensitivity of different vegetation types to ecological disturbance and their restoration potential, and quantitative evaluation of the degree and duration of various factors on vegetation restoration. Simulation and prediction provide data support for developing a scientific vegetation restoration plan.

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