Benefit Analysis of Artificial Restoration Measures in Abandoned Gold Mining Areas of the Altai Mountains Based on Principal Component Analysis and Monitoring Data (Postprint)

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Abstract

This study takes the abandoned gold mining area in the Altai Mountains Two-River-Source Protected Area as the research site. From the four aspects of topography, soil, water, and surface vegetation, and in combination with the existing conditions of the mining area, 11 restoration measures were established. Seven evaluation indicators were selected: richness index, dominance index, diversity index, evenness index, biomass, vegetation coverage, number of species, and soil-to-rock ratio. Using principal component analysis, the principal component scores and ecological benefit rankings of different restoration measures were obtained. The results show that single restoration measures, such as leveling, sheep camping, and mud slurry, essentially consider ecological restoration from only one aspect, have certain deficiencies, and rank relatively low in restoration benefits. Combined measures not only improve the soil environment but also cause changes in plant community diversity patterns, resulting in excellent ecological restoration benefits. For the same restoration measure, longer implementation periods yield better restoration effects.

Full Text

Preamble

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Abstract

Ecological restoration has been widely regarded as an effective approach for mitigating ecological degradation and improving ecosystem service supply. Environmental effects evaluation of ecological restoration—i.e., measuring the ecological restoration extent of damaged ecosystems—is one of the important branches of restoration ecology. Scientific, objective, and accurate assessment of ecological restoration effects is not only an important element of ecological restoration, but could also provide important guidance to the further implementation of ecological restoration.

The "Two River Nature Reserve" in the Altay Mountains is located at the southern slope of the Altay Mountains, Xinjiang, China. This core region is characterized by mountains dissected by river valleys, high levels of precipitation, and high biodiversity. The climate condition of this region is characterized by long cold winters, and short, cool summers. Irrational gold mining activities in this area have caused serious ecosystem degradation and led to the overall degradation or even the loss of ecological functions. In this paper, an abandoned gold mining field in Altay Mountains, Xinjiang was selected as study area. 11 kinds of restoration measures taken by "Two River Nature Reserve Administration" from 2010 to 2015 were examined by calculating the richness index, dominance index, diversity index, evenness index, biomass, vegetation coverage, species number and soil-rock ratio index. Further, the Principal Component Analysis (PCA) was used to compare the efficiency of each artificial measure. The results show that the effects of the single restoration measures, such as leveling, flock, mud and so on was not ideal; The combination of various measures can only improve the soil environment, but also lead to the change of plant community diversity, and the ecological restoration benefits are very good; As far as the same kind of restoration measure is considered, the longer restoration period the better recovery effect. According to a systematic summary of the study progress on effects evaluation of ecological restoration in an abandoned gold mining field in Altay Mountains, this paper supplies a brief account of effects evaluation from the aspects of its content, approach, method and technology.

Keywords: abandoned gold mine; artificial restoration; effects; Principal Component Analysis; Altay Mountains

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Assessment of the Effects of Artificial Restoration Measures in an Abandoned Gold Mining Area in Altay Mountains Using PCA and Monitoring Data

Study Area and Methods

The study area is located in the Two River Nature Reserve in the Altay Mountains, characterized by valley-dissected mountainous terrain, abundant precipitation, and rich biodiversity. The regional climate features long, cold winters

and short, cool summers. Unregulated gold mining activities have caused severe ecological degradation and functional loss in the ecosystem.

Eleven restoration measures implemented by the Two River Nature Reserve Administration between 2010 and 2015 were evaluated using eight indicators: richness index, dominance index, diversity index, evenness index, biomass, vegetation coverage, species number, and soil-rock ratio index. Principal Component Analysis (PCA) was employed to compare the effectiveness of these artificial restoration measures.

Data Analysis

The PCA results extracted principal components with eigenvalues greater than 1. The first principal component explained 46.728% of the variance with an eigenvalue of 3.738, while the second principal component explained 43.347% of the variance with an eigenvalue of 3.468. Together, these two components accounted for 90.075% of the total variance (>85%), indicating they adequately represent the original variables.

The principal component equations were constructed as follows:

$$Z_1 = 0.044y_1 + 0.041y_2 + 0.044y_3 + 0.032y_4 + 0.036y_5 + 0.040y_6 + 0.045y_7 + 0.036y_8$$

$$Z_2 = 0.012y_1 + 0.087y_2 + 0.067y_3 + 0.123y_4 - 0.108y_5 - 0.090y_6 - 0.034y_7 - 0.057y_8$$

The comprehensive evaluation model was:

$$F = \left(\frac{3.738}{7.206}\right) Z_1 + \left(\frac{3.468}{7.206}\right) Z_2$$

where y_1 through y_8 represent the standardized values of the eight evaluation indicators.

Results and Discussion

The correlation coefficient matrix revealed strong interrelationships among most indicators, with correlation coefficients generally above 0.7, confirming the appropriateness of PCA application.

Table 1. Restoration index of different measures

Table 2. Correlation coefficient matrix

The evaluation results demonstrated that single restoration measures (e.g., simple leveling, flocking, or mud application) yielded unsatisfactory outcomes. In

contrast, combined measures not only improved soil conditions but also enhanced plant community diversity, showing excellent ecological restoration benefits. Furthermore, for any given restoration approach, longer implementation periods produced superior recovery effects.

Conclusions

(1) Principal Component Analysis effectively reduces dimensionality while preserving information, making it suitable for comprehensive evaluation of restoration effects. This method provides a scientific basis for assessing and comparing different ecological restoration measures.

(2) PCA offers an objective approach to evaluate restoration effectiveness by integrating multiple indicators, avoiding subjective bias in single-indicator assessments. The method is particularly valuable for guiding future restoration efforts in similar degraded ecosystems.

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Note: Figure translations are in progress. See original paper for figures.