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Vegetation Restoration Technology and Plant Selection in Mine Ecological Restoration

Xiaolei Sheng

Shaanxi Dijian land comprehensive development Co., LTD, Xi'an 710075, China

Abstract: This paper takes the vegetation restoration of mine wasteland as the research object, and discusses the theory and practice of vegetation restoration technology and plant selection principle. It introduces the classification and characteristics of vegetation restoration technology for mine wasteland, including soil improvement technology, seed sowing technology, seedling planting technology and soil and water conservation engineering technology, analyzes the advantages and disadvantages and application scope of various technologies, and proposes the principle of comprehensively considering the feasibility, effectiveness and economy of the technology. Secondly, it expounds the concept and content of plant selection principle, including ecological adaptability principle, biodiversity principle and ecological function principle, analyzes the emphasis and application methods of each principle, and proposes the principle of comprehensively applying these three principles to select suitable plant species and configuration methods. Then, it evaluates the application and effect of plant selection principle, from the aspects of plant species, plant configuration and vegetation restoration effect, verifies the scientificity and effectiveness of plant selection principle, and the ecological and economic benefits of vegetation restoration. Finally, it points out the existing problems and improvement directions of plant selection principle, including the lack of unified standards and methods, sufficient data support and theoretical basis, effective evaluation and monitoring mechanism, etc., and the improvement directions of establishing unified plant selection principle and method, strengthening data collection and analysis, and establishing effective evaluation and monitoring mechanism. This paper has certain reference value and guidance significance for the theory and practice of vegetation restoration of mine wasteland.

Keywords: Abandoned mine, plant restoration, plant selection, restoration effect.

1. Introduction

Mines are important places for human development and utilization of natural resources, and also one of the regions with the greatest impact of human activities on the natural environment[1-3]. In the process of mining, it is inevitable to cause the destruction, desertification and degradation of the land in the mining area, resulting in the imbalance and decline of the ecosystem function in the mining area[4]. Mine wasteland refers to the land that cannot be used normally due to mining activities, including open-pit mining sites, tailings ponds, abandoned shafts, slag piles, etc[5]. Mine wasteland not only occupies a large amount of land resources, but also causes serious pollution and damage to the surrounding water resources, atmospheric resources, biological resources, etc., threatening human health and safety[6].

In order to improve the ecological environment of the mining area, restore the ecological function of the mining area, increase the land use efficiency of the mining area, and achieve the sustainable development of the mining area, mine ecological restoration is an indispensable work. Mine ecological restoration refers to taking a series of technical measures on the mine wasteland, so that it can gradually restore to the land with certain ecological function and economic value, thus realizing the protection, restoration and reconstruction of the ecosystem in the mining area (Figure 1). The main contents of mine ecological restoration include soil restoration, water environment restoration, vegetation restoration and landscape restoration. Among them, vegetation restoration is the core and key of mine ecological restoration, and also the difficulty and focus of mine ecological restoration.

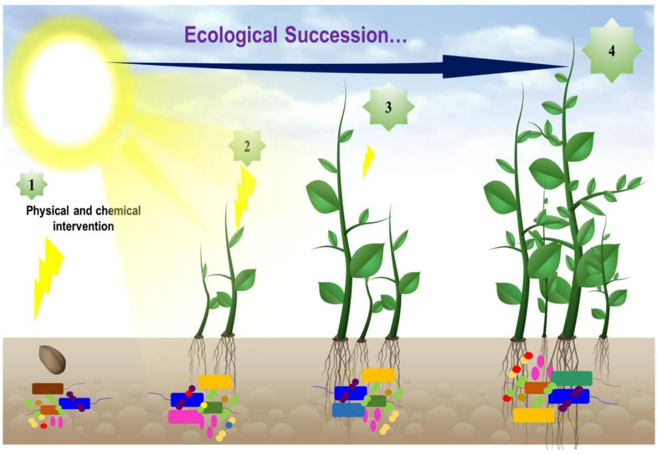

Figure 1. Schematic representation of approaches employed for restoring the mine tailing sites[7].

The main methods of vegetation restoration include soil improvement, seed sowing, seedling planting, soil and water conservation engineering, etc. The key factor of vegetation restoration is the selection of plants, that is, to select suitable plant species and configuration methods on the mine wasteland, so as to achieve the best vegetation restoration effect. Plant selection principle refers to the principle of determining reasonable plant species and configuration methods in the process of vegetation restoration, according to the characteristics and conditions of the mine wasteland, as well as the objectives and requirements of vegetation restoration, comprehensively considering the ecological adaptability, biodiversity and ecological function of plants. Many scholars at home and abroad have conducted in-depth research on this, and achieved some results and experience, but there are still some problems and deficiencies, which need further discussion and improvement[8-11]. This paper aims to comprehensively analyze and evaluate the vegetation restoration technology and plant selection principle in mine ecological restoration, summarize the research status and development trend at home and abroad, explore the existing problems and improvement directions, and provide reference and reference for the practice and theory of mine ecological restoration.

2. Classification and Characteristics of Vegetation Restoration Technology

2.1. Soil Improvement Technology

Applying appropriate amounts of organic or inorganic substances to the mine wasteland to improve the physical, chemical and biological properties of the soil, increase the soil fertility and water retention capacity, and create favorable conditions for the growth of vegetation[12]. The main methods of soil improvement technology include covering organic matter, adding fertilizer, applying lime, mixing clay, etc. The advantages of soil improvement technology are that it can quickly improve the quality of the soil, increase the suitability of the soil, and shorten the time of vegetation restoration. The disadvantages of soil improvement technology are that it requires a lot of material input, high cost, and may cause secondary pollution or ecological imbalance. Soil improvement technology is suitable for mine wasteland with poor soil conditions, such as soil infertility, abnormal pH, high heavy metal content, etc.

2.2. Seed Sowing Technology

Directly or indirectly sowing suitable plant seeds on the mine wasteland to achieve natural or artificial renewal of vegetation. The main methods of seed sowing technology include artificial sowing, aerial sowing, water sowing, animal spreading, etc. The advantages of seed sowing technology are that it is simple to operate, low cost, strong adaptability, and can form a multi-level vegetation structure[13]. The disadvantages of seed sowing technology are that the germination and survival rate of seeds are affected by soil, climate, biological and other factors, which are not easy to control, and require a long time to form a stable vegetation system. Seed sowing technology is suitable for mine wasteland with good soil conditions, suitable climate conditions, and rich plant sources.

2.3. Seedling Planting Technology

Artificially planting plant seedlings that have been nursed or transplanted to achieve rapid establishment and development of vegetation. The main methods of seedling planting technology include hole planting, strip planting, block planting, container planting, etc. The advantages of seedling planting technology are that it can select suitable plant species and configuration methods, ensure the quality and quantity of seedlings, improve the survival rate and growth speed of vegetation, and shorten the time of vegetation restoration. The disadvantages of seedling planting technology are that it requires a lot of human and material input, high cost, and may cause genetic degradation or ecological imbalance of plants. Seedling planting technology is suitable for mine wasteland with poor soil conditions, harsh climate conditions, and lack of plant sources.

2.4. Soil and Water Conservation Engineering Technology

Constructing some soil and water conservation engineering facilities to prevent soil erosion, improve hydrological conditions, and provide water and nutrients for the growth of vegetation. The main methods of soil and water conservation engineering technology include terraces, dams, ditches, ponds, nets, etc. The advantages of soil and water conservation engineering technology are that it can effectively prevent soil erosion, increase water conservation, improve soil fertility and water retention capacity, and create favorable conditions for the growth of vegetation. The disadvantages of soil and water conservation engineering technology are that it requires a lot of human and material input, high cost, and may affect the topography and landscape of the mining area. Soil and water conservation engineering technology is suitable for mine wasteland with steep terrain, high rainfall, and serious soil erosion.

3. Theory and Method of Plant Selection Principle

Plant selection principle refers to the principle of determining reasonable plant species and configuration methods in the process of vegetation restoration, according to the characteristics and conditions of the mine wasteland, as well as the objectives and requirements of vegetation restoration, comprehensively considering the ecological adaptability, biodiversity and ecological function of plants[14]. Plant selection principle is the important basis and key determinant of vegetation restoration effect.

3.1. Ecological Adaptability Principle

When selecting plants, the ecological adaptability of plants and mine wasteland should be considered, that is, whether plants can adapt to the soil, climate, moisture, light and other environmental conditions of the mine wasteland, whether they can resist the ecological pressure of pests and diseases, wind and sand, pollution, etc., and whether they can form a good ecological relationship with the original plants of the mine wasteland. Ecological adaptability principle is the basic principle of plant selection, and also the prerequisite for the success of vegetation restoration. The common methods of ecological adaptability principle include site type division method, plant ecological index method, plant ecological type method, etc.

3.2. Biodiversity Principle

Consider the biodiversity of plants, that is, the diversity of plant species, quantity, structure, function, etc., as well as the diversity between plants and other organisms. Biodiversity principle is an important principle of plant selection, and also an important indicator of vegetation restoration effect. The purpose of biodiversity principle is to increase the ecological stability, resistance, resilience, ecological value and aesthetic value of the mine wasteland. The common methods of biodiversity principle include plant diversity index method, plant configuration pattern method, plant functional group method, etc.

3.3. Ecological Function Principle

The ecological function of plants, that is, the service and contribution of plants to the ecosystem of the mine wasteland, such as soil improvement, water conservation, carbon sequestration and fixation, air purification, biological control, landscape beautification, etc. Ecological function principle is a high-level principle of plant selection, and also a comprehensive evaluation of vegetation restoration effect. The purpose of ecological function principle is to improve the ecological and economic benefits of the mine wasteland, and realize the sustainable utilization of the mine wasteland. The common methods of ecological function principle include plant function evaluation method, plant function weight method, plant function indicator method, etc.

4. Application and Effect of Plant Selection Principles

4.1. Suitable plant species

Choose plant species that can adapt to local soil, climate, moisture, light and other environmental factors, resist pests, wind, sand, pollution and other ecological pressures, and form good ecological relationships with local original plants[15-17] (Figure 2). For example, for mine wastelands with poor soil, abnormal pH, and high heavy metal content, some drought-tolerant, salt-tolerant, and heavy metal-tolerant plant species can be selected, such as Pinus tabuliformis, Tamarix chinensis, Lycoris radiata, etc.; for mine wastelands with steep terrain, high rainfall, and severe soil and water loss, some plant species with developed roots, erosion resistance, and soil and water conservation can be selected, such as Ulmus pumila, Sophora japonica, Lespedeza bicolor, etc.; for mine wastelands with good soil conditions, suitable climate conditions, and rich plant sources, some plant species with ornamental, economic, and ecological values can be selected, such as Osmanthus fragrans, Camellia sinensis, bamboo, etc.

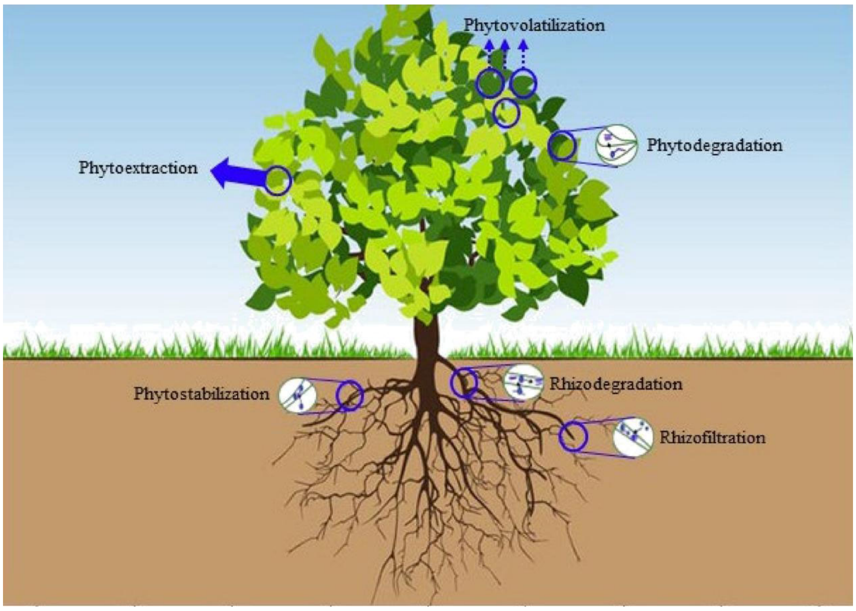

Figure 2. Various pollutant-removal phytoremediation techniques[18].

4.2. Reasonable plant configuration method

Choose the plant configuration method that can achieve the vegetation restoration goal and requirement, such as single configuration, mixed configuration, layered configuration, community configuration, etc. For example, for mine wastelands with poor soil, abnormal pH, and high heavy metal content, single or mixed configuration methods can be used to reduce the competition between plants and improve the survival rate and stability of vegetation; for mine wastelands with steep terrain, high rainfall, and severe soil and water loss, layered or community configuration methods can be used to increase the coverage and diversity of vegetation and improve the erosion resistance and water conservation ability of vegetation; for mine wastelands with good soil conditions, suitable climate conditions, and rich plant sources, mixed or community configuration methods can be used to increase the aesthetic and economic benefits of vegetation and improve the ecological function and service of vegetation.

5. Problems Existing in Plant Selection Principles

5.1. Lack of unified standards and methods

Different researchers and practitioners may adopt different plant selection principles and methods according to their own experience and preference, resulting in inconsistent and even contradictory results of plant selection[19]. For example, some researchers may overemphasize the ecological adaptability of plants, ignoring the biodiversity and ecological function of plants; some researchers may pursue the biodiversity of plants excessively, ignoring the ecological adaptability and function of plants; some researchers may pay too much attention to the ecological function of plants, ignoring the ecological adaptability and biodiversity of plants. These different plant selection principles and methods may lead to unsatisfactory effects of vegetation restoration, or even cause ecological imbalance and environmental pollution.

5.2. Lack of sufficient data support and theoretical basis

Due to the complexity and diversity of mine wastelands, and the variability and uncertainty of plants, plant selection principles need to have sufficient data support and theoretical basis to ensure the accuracy and reliability of plant selection. However, at present, there is a lack of systematic, comprehensive, and long-term data collection and analysis on the environmental factors such as soil, climate, moisture, light, etc. of mine wastelands, and the ecological factors such as ecological adaptability, biodiversity, ecological function, etc. of plants, resulting in the lack of sufficient data support and theoretical basis for plant selection principles. For example, some researchers and practitioners may only judge the ecological adaptability of plants based on the indicators such as pH, organic matter content, heavy metal content, etc. of the surface soil of mine wastelands, ignoring the influence of factors such as soil deep structure, moisture condition, microbial activity, etc.; some researchers and practitioners may only judge the biodiversity of plants based on the indicators such as species, quantity, structure, etc. of plants, ignoring the influence of factors such as plant function, interaction, succession process, etc.; some researchers and practitioners may only judge the ecological function of plants based on the indicators such as soil improvement, water conservation, carbon sequestration, etc. of plants, ignoring the influence of factors such as air purification, biological control, landscape beautification, etc. of plants. These data deficiencies and theoretical gaps may lead to inaccurate and unreliable plant selection, affecting the effect and efficiency of vegetation restoration.

5.3. Lack of effective evaluation and monitoring mechanism

Plant selection principle is a dynamic, iterative, and feedback process, which requires an effective evaluation and monitoring mechanism to ensure the sustainability and optimality of plant selection. However, at present, the evaluation and monitoring mechanism of plant selection lacks clear objectives and standards, scientific methods and means, and sound systems and mechanisms, making it difficult to carry out and implement the evaluation and monitoring work of plant selection.

6. Directions for Improving Plant Selection Principles

Establish unified plant selection principles and methods, and improve the scientificity and standardization of plant selection. In order to avoid the arbitrariness and blindness of plant selection, it is necessary to establish unified plant selection principles and methods, so that different researchers and practitioners can refer to and follow them. Unified plant selection principles and methods should comprehensively consider the ecological adaptability, biodiversity and ecological function of plants, as well as the characteristics and conditions of mine wastelands, and the goals and requirements of vegetation restoration, and form a systematic, scientific and operable plant selection framework. Unified plant selection principles and methods should have the following characteristics: (1) They have universality, and are applicable to different types and conditions of mine wastelands; (2) They have flexibility, and can be adjusted and optimized according to specific situations; (3) They have evaluability, and can effectively evaluate and monitor the results of plant selection.

Strengthen data collection and analysis, and improve the basis and credibility of plant selection. In order to ensure the accuracy and reliability of plant selection, it is necessary to strengthen data collection and analysis, and improve the basis and credibility of plant selection. Data collection and analysis should cover the environmental factors such as soil, climate, moisture, light, etc. of mine wastelands, and the ecological factors such as ecological adaptability, biodiversity, ecological function, etc. of plants, and form a complete, detailed and dynamic data system. Data collection and analysis should adopt scientific, standardized and unified data collection and processing methods, and ensure the quality and validity of data. Data collection and analysis should use modern, advanced and intelligent data analysis and mining techniques, and extract the features and rules of data, and provide strong data support and theoretical basis for plant selection.

Establish an effective evaluation and monitoring mechanism, and improve the sustainability and optimality of plant selection. In order to ensure the sustainability and optimality of plant selection, it is necessary to establish an effective evaluation and monitoring mechanism, so as to timely feedback and adjust the effects and impacts of plant selection. The evaluation and monitoring mechanism should clarify the objectives and standards of evaluation and monitoring, adopt scientific methods and means, and establish sound systems and mechanisms. The evaluation and monitoring mechanism should have the following characteristics: (1) It has comprehensiveness, covering the indicators such as coverage, diversity, stability, functionality, etc. of vegetation, as well as the indicators such as soil, water, air, biology, etc. of mine wastelands; (2) It has dynamism, and can conduct real-time, periodic and long-term evaluation and monitoring according to the growth and change of vegetation, and the environmental and social changes of mine wastelands; (3) It has participation, and can fully utilize the resources and opinions of various parties such as mine managers, workers, residents, etc., and form a diversified, collaborative and win-win evaluation and monitoring system.

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