Journal of Landscape Research 2025, 17(6): 5-8

# Application of Herbaceous Plants in Soil and Water Ecological Restoration of Shuijing Large-Scale Mining Cluster in Shenzhen, China

SUN Fazheng[1], HUANG Chengyan[2], WANG Zuocheng[3], HU Rong[2]

(1. Soil and Water Ecology Professional Committee of Guangdong Provincial Ecological Society, Shenzhen 518131, China; 2. Shenzhen Nature Ecological Garden Technology Co., Ltd., Shenzhen 518131, China; 3. Shenzhen Oufu Chuangzhan Investment Co., Ltd., Shenzhen 518112, China)

**Abstract** The implementation of ecological restoration technologies in different zones of the Shuijing Mining Cluster faces significant variations in difficulty. Through the research, development, and innovative application of herbaceous plant-related restoration technologies, comprehensive revegetation has been achieved even in highly challenging areas. This paper summarizes 6 innovative application technologies of herbaceous plants in the ecological restoration of this mining cluster, namely, composite hydroseeding technology, vegetative material spray-mixing technology, pioneer short-lived grass species technology, biological brick drainage technology, dynamic seed collection and utilization technology, and pond water drip irrigation technology. These approaches provide practical references for soil and water ecological restoration in similar mining areas.

**Keywords** Mine remediation, Soil and water ecological restoration, Herbaceous plants, Technological innovation, Shuijing, Shenzhen

**DOI** 10.16785/j.issn 1943-989x.2025.6.002

The core relationship between humans and nature can be summarized as the relationship between humans and water, humans and soil, and humans and vegetation—that is, the relationship between humans and the soil-water ecosystem[1]. While human production and construction activities alter the natural soil-water ecological patterns, they also gradually construct artificial soil-water ecosystems. Mining and subsequent ecological restoration represent a paradigmatic example of how humans destroy natural soil-water ecosystems and then rebuild artificial ones.

As China's first Special Economic Zone, Shenzhen has experienced urban development intensity and construction pace that rank among the highest in China, leading to prominent issues such as soil erosion and ecological degradation. Consequently, Shenzhen has become one of the earliest cities in China to initiate research and practice on soil erosion control and slope ecological restoration, accumulating substantial technical expertise and engineering achievements[2]. According to statistics of the year 2000, Shenzhen still had 669 exposed slopes resulting from past development activities, which not only caused severe soil erosion but also negatively impacted the urban ecological landscape. Typically composed of rock, these exposed slopes share common challenges of lack of soil, water scarcity, and poor fertility, making ecological restoration technically difficult. Through years of dedicated research and engineering practice, Shenzhen has developed and applied a range of practical technologies, including soil spraying, spray-mix seeding, composite hydroseeding, planting troughs, hanging cage bricks, and biological brick drainage systems. By integrating multiple techniques, the city has optimized the effectiveness of slope remediation[3].

The Shuijing Large-Scale Mining Cluster in Shenzhen is located on the northwest side of Buji Subdistrict, Longgang District, Shenzhen, south of Bulong Road, and traversed by the Qingping Expressway. Covering a total area of 1.713 million $km^2$, it lies within a half-hour transportation radius from the city center, giving it a strategic location and high land-use value. After years of open-pit mining, the area has experienced geological fragmentation, steep slopes, extensive exposed soil, and severe dust pollution, significantly impacting ecological security and the living environment in surrounding built-up areas. In August 2006, Shenzhen Planning Department formulated planning guidelines for the area, establishing an integrated land grading and remediation plan. Following 3 core stages—site grading and remediation, ecological restoration, and planning and construction—the protection and development of land resources have been systematically carried out.

The Shuijing Mining Cluster is divided into 3 zones: the area west of the Qingping Expressway is designated as the Western Zone, which falls within the ecological control line; the area east of the Qingping Expressway is further divided into the Northeastern Zone and the Southeastern Zone, serving as the core engineering rehabilitation areas. These zones compass mines such as Zhenxing, Luoding, Baoluo, Shuijing Fifth, and Huaxing. Following integrated site leveling of these mines and their surrounding areas, the total remediation and ecological restoration area reaches 1.196 million km. Shenzhen Nature Ecological Garden Technology Co., Ltd. began the construction in July, 2018, with the ecological restoration project advancing simultaneously with the main land grading work. By the end of 2021, the land grading project was largely completed, marking an ecological restoration construction period of 13 years—the longest duration and largest scale for a project of its kind in Shenzhen. Through this long-term engineering practice, the project team developed new insights and understanding regarding the technical approaches, construction methods, restoration concepts, and project management of ecological restoration. Herbaceous plants, serving as pioneer species in ecological restoration, are a crucial component of plant community establishment and play an irreplaceable role in mine ecological restoration. Particularly in the early stages of restoration, their rapid growth effectively conserves water and soil, creating suitable site conditions for the subsequent planting of trees and shrubs as well as the natural colonization of wild plants. From the perspective of soil and water ecology, this paper systematically elaborates on the application effectiveness, construction methods, and innovative highlights of herbaceous plants in the ecological restoration of the Shuijing Mining Cluster, aiming to provide reference and facilitate

Received: October 2, 2025 Accepted: November 10, 2025

exchange for similar mine ecological restoration projects.

# 1 Natural overview of Shuijing Mining Cluster and the soil-water ecological characteristics before and after remediation

## 1.1 Natural overview

The Shuijing Mining Cluster is situated within a low mountainous and hilly terrain, characterized by a South Asian tropical maritime monsoon climate. The climatic features are as follows: summers are influenced by the southeast monsoon, resulting in high temperatures and abundant rainfall; winters are affected by the northeast monsoon, northeast trade winds, and cold waves from the north, leading to relatively dry and cool conditions. Key regional climate indicators include: an annual average temperature of 22.4 °C, with the highest monthly average at 28.1 °C and the lowest at 12.1 °C; extreme maximum and minimum temperatures of 36.6 °C and 1.4 °C, respectively; annual accumulated temperature ⩾ 10 °C of 8,107 °C, and frost-free throughout the year; ample precipitation, with an average annual rainfall of 1,948.4 mm, reaching up to 2,662.2 mm in the highest year. Rainfall is concentrated from May to September, which coincides with the typhoon season. Although typhoons making direct landfall average less than 1 per year, those passing nearby often trigger heavy rain or storms. Consequently, the cumulative rainfall during May to September can exceed 2,000 mm. The average annual relative humidity is 79%, the average annual evaporation is 1,755.4 mm, the average annual solar radiation is 523 kJ/cm², and the average annual sunshine duration is 2 280.9 h[4].

## 1.2 Soil and water ecological conditions before remediation

The bedrock of the Shuijing Mining Cluster is primarily granite, with the soil classified as lateritic red earth. The regional elevation ranges from 18 m to 210 m above sea level. The topsoil of the lateritic red earth appears grayish-yellow or reddish-brown, with an organic matter content between 1.38% and 5.25%. It has a high proportion of sand grains and gravel, classifying it as a sandy loam with a granular structure, and a pH value ranging from 4.35 to 5.54. A natural mountain pond is located at the foot of the hillside on the western side of the northeastern zone and the eastern side of the Qingping Expressway, serving as a limited natural water source for the area.

The regional climate, characterized by high temperatures and abundant rainfall along with favorable hydrothermal conditions, is suitable for the growth of various plant species. The zonal vegetation is classified as South Asian subtropical evergreen broad-leaved forest. However, after years of open-pit mining, most of the topsoil in the area has been stripped away, leading to a significant reduction in vegetation coverage. The primary forest vegetation has been completely destroyed, with only secondary forests and plantations remaining on hillslopes, primarily consisting of *Acacia mangium* pure stands, litchi forests, and eucalyptus plantations. The existing main plant species include: *A. mangium*, *Eucalyptus robusta*, *Litchi chinensis*, *Rhodomyrtus tomentosa*, *Melastoma candidum*, *Lantana camara*, *Bougainvillea glabra*, *Dicranopteris linearis*, and *Neyraudia reynaudiana*.

## 1.3 Soil and water ecological conditions after remediation

According to the planning guidelines issued by the Shenzhen Planning Department in August 2006, the Shuijing Mining Cluster underwent zoned land grading and remediation. The Western Zone, located to the west of the Qingping Expressway, has been developed into municipal sanitation facilities. The Northeastern and Southeastern Zones, situated to the east of the expressway, served as the core areas for engineering remediation, where slope protection and ecological restoration works have now been completed. The large expanse of graded land following remediation holds significant development potential due to its advantageous location and is planned for subsequent urban construction use.

As the mining cluster is located in Buji Subdistrict, a major economic hub of Shenzhen, ecological restoration and revegetation of the rehabilitated land must be promptly carried out to restore the natural landscape while effectively preventing soil erosion and dust pollution. This ecological restoration project has achieved a reconstruction of the regional soil-water ecosystem: transforming the originally damaged natural soil-water ecosystem into an artificial one, which will gradually transition into an urban construction land ecosystem in the future. It serves as a typical practice of the concept that "lucid waters and lush mountains are invaluable assets" in the protection and development of mining land resources.

# 2 Application effectiveness of herbaceous plants in ecological restoration of Shuijing Mining Cluster

The difficulty of implementing ecological restoration technologies varied significantly across different geomorphological types within the Shuijing Mining Cluster. Among these, the rock slopes within the excavated areas were steep, with some sections exceeding a gradient of 70°. Effective revegetation of these challenging slopes was achieved through the innovative application of vegetative material spray-mixing technology. Furthermore, the graded land after remediation, characterized by high sand content and some areas being flat ground covered with washed sand tailings, posed substantial difficulties for revegetation as conventional greening techniques proved inadequate. Through repeated experimentation and technological innovation, the project ultimately succeeded in achieving comprehensive revegetation across this area.

Throughout the ecological restoration process, the effectiveness of revegetation varied across different periods, slope types, and soil conditions. The core difference was reflected in the compositional structure of herb-shrub-tree plant communities: in the early stages of spoil areas, vegetation was dominated by herbaceous plants, while trees became the dominant species in the later stages of community succession; on weathered rocky slopes, early vegetation was primarily herbaceous, with shrubs becoming dominant in later stages; on steep rocky slopes, due to site condition limitations, vegetation communities remained dominated by herbaceous plants throughout.

Overall, the ecological restoration project of the Shuijing Mining Cluster has achieved remarkable results, fully meeting the expected goals of soil and water conservation, slope stabilization, natural landscape restoration, and sound ecological conditions. According to field survey data from November 1, 2021, the vegetation coverage rate in all remediated areas reached over 95%. Specific restoration outcomes are presented in Table 1.

# 3 Technological innovations of herbaceous plants in ecological restoration of Shuijing Mining Cluster

To address the varying site conditions and restoration challenges across different zones of the Shuijing Mining Cluster, the project team developed and applied 6 innovative ecological restoration technologies centered on herbaceous plants. These technologies achieved revegetation and effective soil and water conservation in highly challenging areas. The principles, advantages, and application outcomes of each technology are detailed as follows:

### 3.1 Composite hydroseeding technology

Composite hydroseeding technology is a patented national invention. Its core process is as follows: seeds are proportionally mixed with the straw mixture, fertilizers, paper pulp, and water, which is then stirred to form a uniform spraying material. A lightweight gasoline-powered water pump is then used to spray the material onto the surface of slopes or terraces. After regular maintenance, complete vegetation coverage of the exposed slopes and terraces is achieved.

The core advantages of this technology are reflected in 2 aspects: construction adaptability and construction efficiency. Firstly, it is suitable for remote and inaccessible mountainous areas, solving the problem of conventional hydroseeding equipment being unable to access the site for construction. Secondly, it innovatively adopts an air compressor blowing method to mix the spraying materials within the container, achieving efficient and uniform mixing while significantly reducing the cost and labor intensity associated with manual mixing. Engineering practices have demonstrated the remarkable efficiency of this technology, with 3 workers capable of completing hydroseeding operations covering 15,000 $km^2$ in a single day[5].

### 3.2 Vegetative material spray-mixing technology

The slope of the Shuijing Mining Cluster features a maximum height difference of up to 140 m. From the top to the bottom of the slope, soil slopes, weathered rocky slopes, and rocky slopes are distributed sequentially. Among these, the rocky slopes exhibit good stability, and no protective measures were implemented for them in the main engineering works. However, located at the base of the hillside with local gradients exceeding 70°, these rocky slopes are widely recognized within the industry as areas where conventional spray seeding and vegetation establishment techniques struggle to achieve successful revegetation.

Frequent heavy rainfall in Shenzhen poses challenges to conventional spray-mix seeding technology, which relies primarily on plant seeds. The slow germination and growth of seeds, combined with the vulnerability of the sprayed nutrient soil to erosion by rainwater, are the main reasons for the failure of spray-mix seeding on rock slopes steeper than 70°. Previously, greening such steep slopes involved constructing structures such as V-shaped trenches or planting troughs, which were then filled with planting soil for seedling cultivation. However, this method suffers from high construction costs and low greening effectiveness[6].

The innovative aspect of vegetative material spray-mixing technology lies in using locally sourced fresh plant cuttings to partially replace traditional plant seeds. Its core procedure involves: first laying fresh plant cuttings on the surface of rocky slopes according to specifications, followed by spraying a nutrient soil mixture to fully cover the cuttings. These fresh cuttings can quickly sprout and develop into plants, with their root systems growing rapidly. This effectively stabilizes the nutrient soil on the slope surface, reduces the impact of rainwater erosion, and achieves rapid greening of rocky slopes.

### 3.3 Pioneer short-lived grass species technology

Winter temperatures in Shenzhen generally remain above 10 °C, allowing for ecological restoration construction during this season. However, conventional grass species exhibit relatively slow germination and growth rates in winter, leading to a prolonged revegetation period. By leveraging the growth characteristics of pioneer short-lived grass species, the project team optimized the seed mix ratio for winter construction, achieving rapid revegetation and effective soil and water conservation.

The core of this technology involves the application of 2 pioneer short-lived grass species: The first is the cool-season grass species ryegrass (*Lolium multiflorum*), which grows rapidly in winter. It germinates and turns green within approximately 7 d after sowing and can form a complete green turf in about 20 d. This enables it to quickly fulfill functions such as water retention, soil stabilization, and dust prevention, thereby improving the regional landscape. After May each year, ryegrass naturally withers away without affecting the normal growth of other warm-season grass species. The second is the annual plant sesbania (*Sesbania cannabina*), which grows rapidly and can achieve quick revegetation of the area. Simultaneously, it creates suitable site conditions for the growth of other plants. After sesbania naturally withers, other plants can gradually establish and form stable plant communities, ensuring the long-term effectiveness of the ecological restoration.

### 3.4 Biological brick drainage technology

The biological brick drainage technology is a new utility patent technology of China, characterized by excellent ecological and landscape effects, strong ecological functionality, wide applicability, and convenient construction. Its core advantages are reflected in the following aspects: Firstly, it exhibits strong construction adaptability, showing significant advantages in construction within mountainous areas with poor transportation accessibility; it can be constructed using the dry-laying method, allowing normal operation even during rainy weather, with low construction costs. Secondly, it demonstrates good structural stability; on soft filled slopes, it can settle integrally with the slope, preventing masonry fractures caused by slope settlement. Thirdly, the materials are reusable, reducing construction material waste. Fourthly, it offers notable ecological benefits that the biological bricks are manufactured using quarry waste, enabling the resource utilization of solid waste at a low cost[7].

The core process of this technology involves constructing drainage ditches using porous bio-bricks. The pre-drilled holes in these bio-bricks are filled with nutrient soil containing grass seeds. After the seeds germinate and grow, the resulting vegetation covers the brick structure, forming a green drainage ditch. This approach not only fulfills the drainage function but also integrates seamlessly with the surrounding ecological landscape, avoiding the environmental disruption caused by traditional mortar-rubble drainage ditches. Furthermore, the green drainage ditches help reduce rainwater runoff loss, contributing to soil moisture retention and promoting plant growth.

### 3.5 Dynamic seed collection and utilization technology

The ecological restoration project of the Shuijing Mining Cluster spanned 13 years, requiring substantial amounts of plant seeds for hydroseeding operations. Through long-term field observations, the project team found that herbaceous species such as *Neyraudia reynaudiana*, *S. cannabina*, and *Melinis minutiflora*—previously introduced via hydroseeding —exhibited

**Table 1 Ecological restoration effects of the Shuijing Mining Cluster in Shenzhen**

| Landform type after remediation | Subtype | Vegetation coverage rate//% |
|---|---|---|
| Cut slopes | Soil slopes | 100 |
| | Weathered rocky slopes | 98 |
| | Rocky slopes | 95 |
| Fill slopes | — | 100 |
| Flat terrain | Gravel flat | 96 |
| | Tailings flat | 98 |

exceptionally high seed yields. Building on this finding, a dynamic seed collection and utilization technology was developed. The core process involves: systematically studying and mastering the growth habits and seed production characteristics of dominant grass species like *N. reynaudiana* and *S. cannabina*, accurately determining their seed maturation periods; organizing timely manual seed harvesting, and directly applying the freshly collected seeds to subsequent ecological restoration hydroseeding operations.

The core advantages of this technology are as follows: Firstly, the collected seeds exhibit high freshness, with both germination rate and germination potential significantly superior to commercially available seeds, thereby providing high-quality seed sources for ecological restoration. Secondly, as the seeds are self-collected for internal use, they do not need to meet the high purity and high cleanliness standards required for commercial seeds, and thus the seeds may contain a small amount of straw, which can instead create favorable conditions for germination. Thirdly, seed procurement costs are substantially reduced, achieving the recycling of herbaceous plant resources.

### 3.6 Pond water drip irrigation technology

From the perspective of soil and water ecology theory, the core of mine ecological restoration lies in addressing 3 key issues: water, soil, and vegetation—specifically, ensuring water supply for construction and maintenance, configuring suitable planting soil, and selecting localized suitable plant species. There is a natural mountain pond in the western part of the Northeastern Zone of the Shuijing Mining Cluster. Leveraging this local resource, the project team developed and applied a mountain pond water drip irrigation technology, achieving efficient and water-saving supply for maintenance in the restoration areas.

The core procedure of this technology involves pumping water from the mountain pond to a reservoir constructed at the hilltop. This reservoir is then connected to a drip irrigation system covering restoration areas such as rocky slopes. Utilizing the natural topographic elevation difference, gravity-driven water flow is achieved, providing precise irrigation for herbaceous plants and other vegetation on the slopes. By employing drip irrigation for water supply, this method offers advantages such as water conservation, labor efficiency, and effective maintenance. It effectively addresses the challenges of water scarcity and vegetation maintenance difficulties on the rocky slopes of the mining cluster.

## 4 Conclusion

Herbaceous plants play an irreplaceable role in the ecological restoration of water and soil in mining areas. As pioneer species in ecological restoration, they are not only essential components in the construction of plant communities but also, through their rapid growth in the early stages of restoration, effectively conserve soil and water, thereby creating suitable site conditions for the subsequent planting of trees and shrubs as well as the natural regeneration of wild plants. In the ecological restoration project of the Shuijing Large-scale Mining Cluster in Shenzhen, the research, development, and innovative application of herbaceous plant-related restoration technologies are key to achieving comprehensive revegetation in highly challenging remediation areas.

The core objective of technological innovation lies in reducing engineering costs and enhancing restoration effectiveness. The ecological restoration project of the Shuijing Mining Cluster spanned 13 years, during which engineering costs such as labor, fertilizers, and fuel increased significantly. Only through technological innovation was it possible to effectively improve the efficiency of ecological restoration construction, control project costs, and ensure the stability of restoration outcomes. The practice of this project demonstrates that technological innovation in mining ecological restoration originates from practical engineering needs, while the application of innovative technologies, in turn, informs and improves engineering practice, achieving a harmony of ecological, economic, and social benefits.

The 6 innovative technologies summarized in this paper, such as , composite hydroseeding technology, vegetative material spray-mixing technology, pioneer short-lived grass species technology, were all developed based on the specific site conditions of the Shuijing Mining Cluster. They exhibit strong practicality and adaptability, providing technical references and engineering insights for soil and water ecological restoration in similar mining areas in the subtropical regions of southern China. Future efforts may further explore the community combination of herbaceous plants with trees and shrubs, promoting the upgrade of mine ecological restoration from mere "revegetation" to comprehensive "ecosystem recovery," thereby achieving long-term stability of the soil and water ecosystems in mining areas.

## References

[1] Sun, F. Z. (2017). Philosophical thinking on soil and water ecology. *Meteorological and Environmental Research*, (8), 29-33.

[2] Wu, C. W., Zhang, M. T. & Fang, D.Y., et al. (2007). *The method of ecological restorations for exposed hillpits*. Beijing: Science Press.

[3] Research Group on Promotion and Application of Engineering Greening Technology for Rocky Slopes in South China, Shenzhen Water Affairs Bureau. (2014). *Promotion and application of engineering greening technology for rocky slopes in South China*. Beijing: China Water & Power Press.

[4] Chen, T., Li N. & Chen, Y.H., et al. (2006). *Ecological construction of forest landscapes in Shenzhen*. Beijing: China Forestry Publishing House.

[5] Sun, F. Z., Hu, R. & Zhang, Y. D., et al. (2004). Evaluation and application of growing mechanism of Burmareed on cliffs. *Soil and Water Conservation in China*, (7), 18-20.

[6] Wang, Y. J., Wang, Y. X. & Xia, B., et al. (2019). New ideas on ecological rehabilitation of high and steep rock slope based on concrete spray-planting-turf. *Soil and Water Conservation in China*, (1),29-31.

[7] Yin, C. X., Huang, C. Y. & Hu, R., et al. (2013). Development, application, and promotion of biological brick drainage ditch technology. *Soil and Water Conservation in China*, (5), 53-55.