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Study on Vegetation Restoration Technology for Erosion-affected Land in the Gannan Mountain Area: A Case Study of the Ganzhou Hele 220kV Substation

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Abstract: Gannan is located in the southern red soil hilly region, characterized by concentrated rainfall, interlaced ravines, and poor soil structure, which contribute to severe soil erosion. With rapid economic development, various construction projects have been launched, disrupting the surface and destroying the original landforms, making vegetation restoration extremely difficult. This study takes the Ganzhou Hele Substation as an example, applying "W-OH + soil microbes" to the slopes of the substation, with a control group for comparison. Through soil infiltration tests, soil erodibility modeling, organic matter content analysis, and plant root vitality assessments, the effectiveness of vegetation restoration on erosion-affected land slopes in the Gannan mountainous region under different configuration modes was verified. The results show that the W-OH material significantly reduces water infiltration in the eroded soils of the Gannan mountain area, enhances soil erosion resistance, and the soil microbes effectively increase soil organic matter content and plant root vitality. The combined application of both is complementary. The configurations "soil microbes + 3.0% W-OH" and "soil microbes + 4.0% W-OH" are more beneficial to the rapid restoration of vegetation in the erosion-affected land in the Gannan mountainous region.

Keywords: Gannan Mountain Area, W-OH material, soil microbes, vegetation restoration

Gannan is located at the southern edge of the middle subtropical zone and belongs to the southern red soil hilly region. Due to adverse natural conditions such as concentrated rainfall, interlaced ravines, and poor soil structure, soil erosion is highly prone to occur. Land that becomes barren and difficult to utilize due to erosion is referred to as erosion-affected land. In Gannan, the uneven distribution of rainfall across both spatial and temporal scales, along with the acidic, sticky, and poor nature of the red soil, results in a lack of the essential nutrients and moisture required for plant growth, leading to slow vegetation recovery or even plant death.

With the advancement of urbanization and rapid economic development, numerous production and construction projects have been launched. While these projects bring economic benefits and social development, they also cause considerable damage to the ecological environment [1]. Among these, power transmission and transformation projects, which involve both point and linear constructions, inevitably disturb the surface through activities such as land clearing, excavation, and backfilling during construction, which damages the original landforms and vegetation, resulting in

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soil compaction and a decline in soil fertility. This makes vegetation restoration extremely difficult, leading to soil erosion and other ecological issues that severely degrade the regional environment [2-3]. Research has shown that the implementation of soil and water conservation measures through vegetation in mountainous power transmission and transformation projects has yielded significant water and soil conservation benefits, substantially reducing soil erosion [4]. Therefore, vegetation restoration is of great significance for mitigating problems such as grassland degradation, soil desertification, and soil erosion caused by power transmission and transformation projects [5].

This study takes the Ganzhou Hele Substation as an example, applying "W-OH (a new hydrophilic polyurethane material) + soil microbes" to the slopes of the substation to verify the feasibility of rapid vegetation restoration in erosion-affected land in the Gannan mountainous region.

1. Materials and Methods

1.1. Overview of the Study Area

Ganzhou City features typical hilly landforms and belongs to the southern red soil hilly region, characterized mainly by hydraulic erosion. The allowable soil loss rate is 500 t/(km²·a). The average annual temperature in the Gannan region is 19.2°C, with an average annual rainfall of 1607.6 mm. Rainfall is intense, and the number of rainy days is high. The predominant soil type is red soil developed from granite parent material, with a texture mainly consisting of sandy loam, which is the main area for landslides. According to the "Jiangxi Province Soil and Water Conservation Bulletin (2023)," the area of moderate and severe hydraulic erosion in the province is 22,786.67 km², accounting for 13.64% of the total land area. Among the 11 prefecture-level cities in the province, Ganzhou has the largest area of soil erosion, covering 6,673.47 km², which accounts for 16.95% of its total land area.

1.2. Experimental Materials

W-OH is a new hydrophilic polyurethane material that uses water as a curing agent. It is characterized by low cost, ease of construction, and environmental friendliness [6]. Its chemical formula is (OCN-R-NCO)n, and it appears as a light yellow to brown oil-like substance with a normal temperature density of 1.18 g/cm³ and a viscosity of 650-700 mPa·s. The curing time ranges from 30 to 1800 seconds and has the following properties [7]:

① It dissolves easily in water and quickly polymerizes into an elastic gel after reacting with water, becoming insoluble in water.

② It can react with water in any ratio and can react with various types of water.

③ It has good durability.

④ It has strong adhesion to materials such as soil, sand, and concrete.

⑤ By adjusting the concentration of W-OH, the gel's performance and applications can be tailored, such as soil stabilization, dust control, water sealing, etc.

⑥ It does not cause phytotoxicity and does not lead to secondary environmental pollution.

Soil microbe configuration: Bacillus subtilis (DL1), Trichoderma harzianum (DL2), and Bacillus licheniformis (DL3) were first introduced into a liquid culture medium and shaken for 24 hours. They were then transferred to a fermentation tank. During fermentation, soil microbe samples were periodically taken to measure their wet weight. When the fluctuation curve peaked and then dropped for the first time, the microbes were transferred to a sterilized plastic bottle. A mixed solution of the three types of microbes was prepared in equal proportions, with each microbial configuration containing 100 mL, and was added to the spraying substrate.

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1.3. Experimental Layout

The Ganzhou Hele 220 kV substation is located in Shizhu Village, Shuixi Town, Zhanggong District (N25°56'08.28", E114°53'47.53"). The experimental site is situated on the southeastern slope of the access road to the substation. The study design included two concentration gradients of the W-OH solution (3.0%, 4.0%) and one control (0.0%). The W-OH solution was sprayed at a standard rate of 3.0 L/m², and the substrate containing soil microbes was sprayed at 2.0 L/m² onto the soil surface of the experimental area. Four experimental plots were set up on site, each measuring 2.5 m in length and 1.0 m in width. The plots were labeled as follows: control group, soil microbes, soil microbes + 3% W-OH, and soil microbes + 4% W-OH.

The specific construction procedures were as follows:

① Slope Surface Preparation — Ensure the slope is level, permeable, and suitable for construction.

② Soil Microbe Spraying — The substrate with added soil microbes was evenly sprayed onto the slope of the sample plot.

③ Grass Seeding — Grass species (such as Festuca arundinacea) suitable for local growth were selected and broadcasted. After sowing, the seeds were raked to ensure they were covered with soil, preventing seed loss.

④ W-OH Spraying — To ensure successful spraying, the W-OH solution was mixed immediately before spraying to prevent premature curing, which could interfere with application.

⑤ Post-application Maintenance and Observation — Regular sampling and observation were conducted, focusing on soil basic physical and chemical properties, as well as nitrogen, phosphorus, and potassium content.

1.4. Sample Collection and Analysis

Soil samples for the experiment were collected in August, October, and December 2024, with three sets of replicates per sample group. The soil samples were divided into core samples and bulk soil samples.

Core samples were taken from the upper, middle, and lower parts of each plot, with each sample being a repeat. During sampling, the core sampler was pressed vertically into the soil until resistance was felt, then it was removed, and the soil within the sampler was carefully extracted and placed in a drying box, using a balance to weigh the sample. Excess soil from both ends of the sample was trimmed off.

Bulk soil samples were collected using a five-point sampling method. First, the midpoint of the diagonal line of the plot was identified as the central sampling point. Then, four other points, each 1.0 meter from the central point along the diagonal, were selected as sampling points. Equal amounts (50g) of soil were taken from each of the five points, mixed together, and used as a composite sample.

The soil bulk density was measured using the drying method; the saturated soil hydraulic conductivity was measured using the constant head method; mechanical composition was determined using ultrasonic dispersion of soil aggregates, wet sieving for sand separation, and continuous centrifugation for separating silt and clay particles; the organic matter content of the soil was determined using the sulfuric acid potassium dichromate heating-titration method; root vitality was measured using a colorimetric method [8].

1.5. Experimental Design and Data Processing

The new hydrophilic polyurethane material W-OH has excellent impermeability, effectively preventing water penetration [7], and protecting soil and groundwater resources. The use of W-OH materials for the treatment of eroded land can address the shortcomings of traditional materials, such as poor erosion resistance and adhesion, improve soil moisture retention and nutrient retention, and reduce the loss of soil nutrients caused by erosion. This will effectively promote vegetation recovery in the erosion-prone areas of the mountainous regions of southern Jiangxi. A 2012 study by Guo Kaixian showed that W-OH materials possess antifreeze, compressive, tensile, and UV-resistant properties, and achieved good results in vegetation recovery and sand control around the Qinghai Lake area [9]. In 2014, Yu Yingying found that W-OH had a good solidification effect on sandy soil and could rapidly reduce the soil's erosion intensity [10]. The permeability and erosion resistance of soil play a significant role in the occurrence and development of soil erosion [11], so this study designed soil permeability tests and erosion susceptibility models to verify the effect of W-OH materials in reducing soil permeability and enhancing erosion resistance in the erosion-prone soils of southern Jiangxi.

The soil microorganisms contain thermophilic bacteria, mesophilic bacteria, filamentous fungi, hydrogen bacteria, actinomycetes, etc. These microorganisms decompose organic matter to produce organic acids and inorganic nutrients [12], creating a higher-order aggregate structure in the soil and promoting the formation of plant mycorrhizae [13]. Based on this, the study improved the soil spraying technique by adding effective soil microorganisms to the spraying matrix, utilizing highly efficient soil-active microorganisms to accelerate the soil formation process from rocks [14], rapidly forming the soil required for plant survival, ensuring long-term effectiveness in vegetation restoration. This study verified the effect of soil microorganisms on the rapid recovery of vegetation in the eroded land of southern Jiangxi by measuring soil organic matter content and root vitality.

1.5.1. Soil Permeability Test

The infiltration of water has a significant impact on the occurrence and development of soil erosion on slopes. In this study, the constant head method [8] was used to analyze the effect of W-OH materials on the saturated hydraulic conductivity of soil in the erosion-prone areas of southern Jiangxi. The test soil samples were weighed and placed in trays to soak for 48 hours to achieve water saturation. During soaking, the water level was maintained at half the height of the core sampler. Before starting the experiment, the water head was adjusted, and the saturated soil samples were placed in the soil chamber of the testing device to begin measurements. Once the water flow stabilized, timing began, and the outflow was measured every three minutes, with three measurements taken in total. The average value was calculated, and the saturated hydraulic conductivity was then determined.

Saturated hydraulic conductivity refers to the ability of water to pass through saturated soil in a unit of time per unit area, reflecting the infiltration and leaching properties of the soil. It is an important parameter for studying the movement of water and solutes in soil [15]. Studying the permeability characteristics of soils in the erosion-prone areas of southern Jiangxi helps analyze how their permeability affects the formation of soil erosion, and provides a basis for reducing permeability and enhancing soil stabilization in mountainous erosion-prone regions. The calculation formula is as follows:

$$K_s = \frac{QL}{ATH}$$

Where: K_s is the saturated hydraulic conductivity (mm/min); Q is the outflow (cm^3); A is the cross-sectional area of the soil column (cm^2); T is the measurement time (min); L is the length of the soil column (mm); H is the water head during measurement (cm).

1.5.2. Soil Erosivity Model Calculation

Soil erosivity reflects the ease with which soil is dispersed and transported under the combined effects of raindrop impact and runoff. Calculating the erosivity of surface soil on slopes helps reflect its sensitivity to slope runoff erosion. In this study, the K-value for erosivity from the EPIC model was used for calculation:

$$K_{EPIC} = \{0.2 + 0.3\,exp[-0.0256SAN(1.0 - SIL/100)]\} \times [SIL/(CLA + SIL)]^{0.3} \times \{1.0 - 0.25C/[C + exp(3.72 - 2.95C)]\} \times \{1.0 - 0.7SN1/[SN1 + exp(-5.51 + 22.9SN1)]\}$$

Where: SAN is the sand content (0.05–2.0 mm) (%); SIL is the silt content (0.002–0.05 mm) (%); CLA is the clay content (<0.002 mm) (%); SN1 = 1 – SAN / 100; C is the organic carbon content (%), which can be derived from the soil's organic matter content.

1.5.3. Soil Organic Matter Calculation

Under external heating, a specific amount of standard potassium dichromate-sulfuric acid solution is used to oxidize soil organic matter (carbon), and the remaining potassium dichromate is titrated with standard ferrous sulfate. The organic carbon content is calculated from the amount of potassium dichromate consumed, and the organic matter content is then indirectly calculated. Generally, the average carbon content in soil organic matter is 58%, so to convert it to organic matter, the value should be multiplied by 100/58 = 1.742. Additionally, since this method oxidizes about 90% of the soil organic matter, the measured result should be multiplied by a correction factor of 100/90 = 1.1. The formula for calculating organic matter (%) is as follows:

$$\text{Organic Matter (\%)} = \frac{(\text{V0} - \text{V})\text{N} * 0.003 * 1.724 * 1.1}{\text{Dry Soil Weight (g)}} * 100$$

Where: V_0 is the volume of $FeSO_4$ consumed during the blank titration (mL); V is the volume of $FeSO_4$ consumed during the sample titration (mL); N is the equivalent concentration of $FeSO_4$; 0.003 is the mass of carbon equivalent to 1 milligram (g).

1.5.4. Root Vitality Calculation

This study used the TTC (2,3,5-triphenyl tetrazolium chloride) colorimetric method to measure root vitality. The dehydrogenase in plant roots can cause a reduction reaction in TTC, allowing the reduction amount of TTC to be used as an indicator of dehydrogenase activity and, consequently, root vitality. The formula for calculating root (dehydrogenase) activity (mg/g·h) is as follows:

Root (Dehydrogenase) Activity (mg/g·h) = C × V / (1000 × W × t)

Where: C is the concentration of the sample extract (μg/ml) obtained from the standard curve; V is the total volume of the sample extract (mL); W is the weight of the plant root (g); t is the incubation time (h) = 19h.

2. Results and Discussion

2.1. The Effect of W-OH Concentration on Slope Soil Permeability in the Gannan Mountain Area

Upon contact with water, the W-OH material rapidly forms a gel, solidifies, and creates an elastic, porous consolidation layer. In 2016, Zhu Yayun applied W-OH material to the treatment of collapse slopes in Changting, Fujian. The experimental results showed that applying a W-OH concentration of 3.0% to 4.0% in erosion-prone areas with water flow power less than 40 $kg \cdot s^{-3}$ effectively inhibited erosion [16]. Considering the water requirements of plants and the impact of infiltration on slope soil erosion, this study selected W-OH solutions with concentrations of 3.0% and 4.0% based on the actual project conditions.

Comparison of soil sample measurements from August and December 2024 (Table 1) showed that the saturated hydraulic conductivity of soil samples without W-OH treatment increased by 62.5%.

Soil samples treated with W-OH solutions at different concentrations reduced the saturated hydraulic conductivity to varying degrees. The 3.0% W-OH solution reduced the saturated hydraulic conductivity by 73.7%, while the 4.0% W-OH solution reduced it by approximately 83.4%. It can be seen that applying W-OH material reduces the saturated hydraulic conductivity of the surface soil on erosion-prone slopes. The 3.0% concentration of W-OH solution reduced the saturated hydraulic conductivity by more than 50%, and as the concentration of W-OH solution increased, the reduction in saturated hydraulic conductivity became more pronounced.

Table 1: The Decrease Rate of Saturated Hydraulic Conductivity under Different Concentrations of W-OH Solution Treatment

W-OH Solution Concentration (%)	0	3.0	4.0
Ks (2024.08)/(mm/min)	0.08	0.19	0.18
Ks (2024.12)/(mm/min)	0.13	0.05	0.03
Ks Decrease Rate (%)	-62.5	73.7	83.4

Note: The W-OH solution concentration in this paper refers to mass concentration.

2.2. The Effect of W-OH Concentration on Soil Erodibility in the Gannan Mountain Area

Soil erodibility refers to the soil's sensitivity to erosion, which is the reciprocal of its resistance to erosion, typically represented by the K value. Under identical conditions such as rainfall, soils with higher erodibility are more prone to erosion than soils with lower erodibility. Based on the basic physical and chemical properties of the experimental soil, the erodibility K values were calculated (Table 2). The results showed that the K value of the soil sample without W-OH treatment was 0.2074 in August 2024 and 0.2313 in December 2024, with an increase of 0.0239. The K value of soil samples treated with a 3.0% W-OH solution was 0.2490 in August 2024 and 0.2197 in December 2024, with a decrease of 0.0292. The K value of soil samples treated with a 4.0% W-OH solution was 0.2800 in August 2024 and 0.2515 in December 2024, with a decrease of 0.0285.

It can be observed that the K values of soil samples treated with different concentrations of W-OH solutions decreased to varying degrees. Specifically, the erodibility of untreated soil increased by 11.53%, while the erodibility of soil treated with a 3.0% W-OH solution decreased by 11.74%, and that treated with a 4.0% W-OH solution decreased by 10.19%. The 3.0% W-OH solution was most effective in reducing the soil erodibility in the test area.

Table 2: The Decrease Rate of Soil Erodibility K Value under Different Concentrations of W-OH Solution Treatment

W-OH Solution Concentration (%)	0.0	3.0	4.0
K Value (2024.08)	0.2074	0.2490	0.2800
K Value (2024.12)	0.2313	0.2197	0.2515
K Decrease Rate (%)	-11.53	11.74	10.19

2.3. The Effect of Different "Soil Bacteria + W-OH" Configuration Modes on Organic Matter in the Slope Soil of the Gan'nan Mountain Area

Soil organic matter refers to carbon-containing organic compounds that exist in various forms in the soil. After decomposition, organic matter can release various trace elements such as nitrogen, phosphorus, potassium, and calcium, providing essential nutrients for plant growth. Based on the

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measured organic carbon content of the sample soils, the organic matter content was calculated. The results are shown in Table 3. It can be seen that the application of soil bacteria effectively increases soil organic matter content. Specifically, the soil organic matter content increased by 3.05% when only soil bacteria were applied, increased by 45.87% when “soil bacteria + 3.0% W-OH” was applied, and increased by 77.70% when “soil bacteria + 4.0% W-OH” was applied. The “soil bacteria + 4.0% W-OH” configuration mode showed a significant effect on increasing soil organic matter content.

Table 3: The Increase Rate of Soil Organic Matter Content under Different “Soil Bacteria + W-OH” Configuration Modes

Configuration Mode	Control Group	Soil Bacteria	Soil Bacteria + 3.0% W-OH	Soil Bacteria + 4.0% W-OH
Organic Matter Content (%) (2024.08)	1.40	1.08	0.90	1.14
Organic Matter Content (%) (2024.12)	0.97	1.11	1.31	2.03
Organic Matter Increase Rate (%)	-30.99	3.05	45.87	77.70

Note: The control group refers to the group with no addition of soil bacteria and no addition of W-OH solution.

2.4. The Effect of Different “Soil Bacteria + W-OH” Configuration Modes on Plant Root Activity

Plant root activity is one of the important indicators for evaluating plant growth and health. Plants with strong root activity have faster root growth and can quickly adapt to environmental changes, thereby improving plant resistance and yield. Comparing the root activity results from August and December 2024 (Table 4), the control group showed a root activity increase rate of -46.47%, plants with only soil bacteria had a root activity increase rate of -46.47%, plants treated with “soil bacteria + 3.0% W-OH” showed an increase rate of 924.70%, and those treated with “soil bacteria + 4.0% W-OH” showed an increase rate of 648.85%. The application of “soil bacteria + W-OH” significantly enhanced the root activity of plants in the erosion-prone areas of the Gan’nan mountain region, with the “soil bacteria + 3.0% W-OH” configuration mode showing a more obvious effect.

Table 4: The Increase Rate of Root Activity under Different “Soil Bacteria + W-OH” Configuration Modes

Configuration Mode	Control Group	Soil Bacteria	Soil Bacteria + 3.0% W-OH	Soil Bacteria + 4.0% W-OH
Root Activity (mg/g·h) (2024.08)	2.02	1.80	1.52	1.29
Root Activity (mg/g·h) (2024.12)	1.08	0.85	15.55	9.69
Root Activity Increase Rate (%)	-46.47	-52.94	924.70	648.85

3. Conclusions and Prospects

In the infiltration and erosion resistance tests, the W-OH material showed significant water infiltration reduction effects. A 3.0% concentration of W-OH solution was able to reduce the saturated hydraulic conductivity of the slope soil in the erosion-prone areas of the Gan’nan mountain region by more than 50%. As the solution concentration increased, the reduction effect of W-OH material became more pronounced. The W-OH material effectively decreased the soil erodibility K-value, enhancing the erosion resistance of the slope soil.

It can be concluded that W-OH material not only reduces water infiltration into the slope soil of erosion-prone areas in the Gan’nan mountain region, thereby increasing the soil’s resistance to erosion, but also promotes plant germination and growth on the slopes. The application of soil bacteria

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effectively improves the organic matter content and root activity of the soil in the erosion-prone areas of the Gan'nan mountain region. When combined, the effects are even better. The "soil bacteria + 3.0% W-OH" and "soil bacteria + 4.0% W-OH" configuration modes are more beneficial for the rapid restoration of vegetation in the erosion-prone areas of the Gan'nan mountain region.

The findings of this study can be applied to vegetation restoration in construction projects on erosion-prone lands in the later stages of the construction process in the Gan'nan mountain region. These results can help restore degraded land into usable land, enhance vegetation recovery, and improve the ecological environment. However, this study primarily focuses on the linear changes in soil indicators and root activity due to the application of "W-OH + soil bacteria," reflecting their positive effects to some extent. The study of the soil erosion and vegetation recovery processes is still insufficient. Future research should explore the effect of "W-OH + soil bacteria" applications on vegetation recovery in the Gan'nan mountain region from different perspectives and at different stages.

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References

[1] Ji, X., Yang, J., Liu, J., et al. (2023). Analysis of spatial-temporal changes and driving forces of desertification in the Mu Us Sandy Land from 1991 to 2021. Sustainability, 15(13), 10399.

[2] Liu, Q., Li, X., Jiang, S., et al. (2022). Key issues and development trends of ecological slope protection in transmission and transformation engineering. Yangtze River, 53(Supplement 1), 16-20.

[3] Lei, L., Wan, H., Wei, J., et al. (2020). Analysis of soil and water conservation in ultra-high voltage transmission and transformation engineering. Chinese Journal of Soil and Water Conservation, (1), 16.

[4] Lu, J., Pang, J., Zhao, Q. (2024). Study on soil erosion and soil and water conservation characteristics in mountainous transmission and transformation engineering: A case study of the Yuchu DC back-to-back interconnection project. Chinese Journal of Soil and Water Conservation, (11), 80-84.

[5] Xu, Y., Jin, G., Dang, W., Wang, X., & Li, C. (n.d.). Effect of nitrogen and phosphorus fertilizers on vegetation restoration in the tower foundation disturbance area of the transmission and transformation project in the Horqin Sandy Land of Inner Mongolia. Chinese Journal of Soil and Water Conservation Science (Chinese & English). Retrieved from https://link.cnki.net/urlid/10.1449.S.20241015.1702.002

[6] Gao, W., Wu, Z., Wu, Z., et al. (2010). Study on the mechanical properties of new desertification prevention material W-OH. Journal of Soil and Water Conservation, 24(5), 1-5.

[7] Wang, L. (2011). Application study of the new anti-seepage material W-OH in high-cold arid region channels. Water-Saving Irrigation, (4), 28-30.

[8] Zhang, G. (2012). Soil survey laboratory analysis methods (Vol. 1). Beijing: Science Press.

[9] Guo, K. (2012). Characteristics of the W-OH new material and its application in sand fixation in desertified areas around Qinghai Lake. Chinese Rural Water Resources and Hydropower, (4), 30-32.

[10] Yu, Y., Wang, Y., Fan, J., et al. (2014). Application of W-OH ecological slope protection technology on riverbank slopes in sandy areas. Science and Technology Promotion and Application, (8), 31-32.

[11] Yu, X., Bi, H., et al. (2013). Soil and water conservation science (Vol. 1). Beijing: China Forestry Publishing House.

[12] Maike, H., Nico, E., & Stefan, S. (2008). Seasonal changes in the soil microbial community in a grassland plant diversity gradient four years after establishment. Soil Biology and Biochemistry, 40, 2588-2595.

[13] Shi, Z., Zhang, X., & Wang, F. (2010). Effects of mycorrhizal fungi on soil respiration. Journal of Ecology and Environment, 19(1), 233-238.

[14] Wang, L., Zhang, J., Meng, L., et al. (2011). Effects of soil bacteria on plant growth and physical structure of spraying matrix. Journal of Soil and Water Conservation, 25(2), 144-152.

[15] Zheng, J., Shao, M., & Zhang, X. (2004). Spatial variation characteristics of surface soil bulk density and saturated hydraulic conductivity on slopes in the Loess Plateau. Journal of Soil and Water Conservation, 18(3), 53-56.

[16] Zhu, Y. (2016). Study on the collapse slope erosion sensitivity and erosion control of W-OH material based on water flow power (Doctoral dissertation). Nanjing Institute of Soil Research, Chinese Academy of Sciences.