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Study on the Slope Protection Effect of Different Vegetation Types in Ditch and Land Reclamation

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Abstract

This article focuses on improving the effectiveness of slope protection and proposes a series of effective strategies. In terms of vegetation selection, based on local natural conditions, drought tolerant vegetation such as lemon and sea buckthorn are selected in arid areas, rhododendrons and tea trees are selected in acidic soil areas, and Robinia pseudoacacia and Lespedeza are selected in steep slopes, emphasizing the synergistic combination of trees, shrubs, and grasses. In terms of configuration mode, a layered configuration is adopted, with tall trees such as poplar and willow planted on the upper layer, shrubs such as purple locust and thorns planted on the middle layer, and herbaceous plants such as ryegrass and clover planted on the lower layer. Mixed planting of leguminous and non leguminous plants is also promoted to increase vegetation diversity. In the later maintenance and management, reasonable irrigation and fertilization should be carried out according to vegetation needs and soil moisture conditions. Drip irrigation and sprinkler irrigation should be used to ensure water in dry seasons, organic fertilizer should be applied in spring and autumn, and chemical fertilizer should be applied during vigorous growth periods; At the same time, the comprehensive use of biological, physical, and chemical methods to prevent and control pests and diseases, regular inspections, and ensure the effectiveness of slope protection provide scientific guidance for slope protection projects.

Keywords

Slope Protection; Vegetation Selection; Vegetation Configuration; Maintenance Management.

1. Introduction

In the context of ecological protection and optimized utilization of land resources, the importance of ditch and land reclamation projects has become increasingly prominent. This project plays a key role in increasing arable land area, improving regional ecological environment, and promoting agricultural development through the systematic improvement of channels. However, during the implementation of the project, the stability of the slope was significantly reduced due to the reshaping of terrain and changes in soil structure. Slope instability may not only trigger geological disasters such as landslides and mudslides, threatening the safety of surrounding residents' lives and property, but also cause serious

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damage to the ecological environment, exacerbate soil erosion, and lead to ecosystem imbalance. Therefore, effective slope protection has become a key factor in the success or failure of ditch and land reclamation projects.(He et al. 2021).

Vegetation slope protection, as an eco-friendly slope protection method, has many advantages(Zhu et al. 2024). It can not only improve the ecological environment, increase oxygen content and absorb carbon dioxide through photosynthesis of vegetation, provide habitats for organisms, promote biodiversity development, but also bring considerable economic benefits. Compared with traditional engineering slope protection, it can significantly save material and labor costs in large-scale protection projects(Zhu et al. 2022). In addition, vegetation slope protection can harmonize the slope with the surrounding environment and improve the quality of regional landscape(Zhu et al. 2022). Different vegetation types play different roles in slope protection due to their unique biological characteristics, such as root structure, plant morphology, growth habits, etc. In depth exploration of the effects of different vegetation types on slope protection in gully and land reclamation can help screen vegetation combinations that are suitable for different regional geological and climatic conditions, optimize protection plans, effectively improve slope stability and ecosystem sustainability, and have significant implications for ensuring the long-term stable operation of gully and land reclamation projects and the healthy development of the ecological environment(Szymura, Szymura, and Dunajski 2011).

Research on vegetation slope protection started earlier in foreign countries, with fruitful achievements in mechanical mechanisms, hydrological effects, and other aspects. Through a large number of field experiments and numerical simulations, the reinforcement effect of vegetation roots on soil has been revealed(Xu et al. 2024). For example, deep rooted plants can deeply anchor the soil, improve the anti sliding ability of slopes, and the impact of vegetation coverage on slope runoff and soil erosion, such as the ability of branches and leaves to intercept rainwater and reduce slope runoff velocity. In the research of ditch and land reclamation, foreign countries pay attention to the integrity and sustainability of ecosystems, and often adopt comprehensive ecological engineering measures for slope protection(Zhu et al. 2022; Zhang et al. 2017; Lan and Dong 2022). With the large-scale promotion of ditch and land reclamation projects in China, research on slope protection continues to deepen, covering various aspects of vegetation slope protection, including vegetation adaptability, protection effect evaluation, vegetation soil interaction, etc. Rich data has been accumulated through field monitoring and indoor experiments(Cole 1995). However, there is still room for improvement in the systematic comparison of protective effects of different vegetation types, regional adaptability research, and long-term stability monitoring(Chahar and Vadodaria 2010).

This article will classify and introduce the common types of slope protection vegetation in ditch and land reclamation, and deeply analyze their biological characteristics, adaptability to the environment, and planting points; Explore the influencing factors of slope protection effects of different vegetation types, including vegetation itself, soil, climate, slope characteristics, etc; Finally, strategies and suggestions are proposed to improve the effectiveness of slope protection, providing scientific basis for slope protection engineering in ditch and land reclamation. During the research process, the literature review method will be used to sort out domestic and foreign research results and grasp the research trends; Using case analysis method to analyze typical projects; Summarize the differences in protection under different conditions using comparative research methods.

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2. Overview of Gully and Land Reclamation Engineering and Slope Protection

2.1. Introduction to Ditch and Land Reclamation Project

Ditch control and land reclamation is a comprehensive project that involves building dams, embankments, and leveling land in a ditch to transform barren ditches into usable land. Its significance goes far beyond increasing arable land, but also lies in improving ecology, enhancing land quality, promoting regional sustainable development, effectively controlling soil erosion, regulating flood runoff, and improving soil fertility. In recent years, the land reclamation project has achieved significant results in many areas, such as the addition of a large amount of high-quality arable land in northern Shaanxi, which has curbed soil erosion. In the future, with the advancement of technology and the popularization of ecological concepts, engineering will develop towards ecologicalization and intelligence, paying more attention to the integrity and stability of the ecosystem, and using advanced technology to improve quality and efficiency.

In recent years, the ditch and land reclamation project has been fully implemented in many parts of China, with a large scale and remarkable achievements. According to relevant statistics from the Department of Natural Resources of Shaanxi Province, after the large-scale promotion of ditch and land reclamation projects in northern Shaanxi, the per capita arable land area of local farmers has significantly increased, with an average increase of about 0.5 acres of arable land per person. Due to the good quality of newly added arable land, optimized irrigation and cultivation conditions, crop yields have significantly increased. Taking corn as an example, the yield per mu has increased by 15% -20% compared to before. Based on the comprehensive increase in crop yields, the per capita annual income of farmers has increased by about 20%, effectively promoting their income growth. Looking ahead to the future, with the rapid progress of technology and the deep popularization of ecological concepts, the ditch and land reclamation project will accelerate towards ecological and intelligent direction. In terms of ecologicalization, the project will pay more attention to the integrity and stability of the ecosystem. For example, in vegetation selection, local native plants are preferred to better adapt to the local ecological environment and promote the natural succession and balance of the ecosystem. At the same time, we will strengthen the ecological restoration of channel water systems, build a sound wetland ecosystem, enhance the self purification capacity of water bodies, and improve the regional water environment. In terms of intelligence, advanced monitoring technology and management methods will be widely applied. With the help of satellite remote sensing, unmanned aerial vehicle monitoring and other technologies, real-time and accurate information on slope stability, vegetation growth status, and soil moisture can be obtained. Utilizing big data analysis and artificial intelligence algorithms to deeply mine and analyze monitoring data, providing scientific decision-making basis for engineering planning, construction, and later maintenance. In addition, intelligent irrigation and fertilization systems will accurately regulate water and fertilizer supply based on plant growth needs and soil fertility conditions, improve resource utilization efficiency, reduce labor costs, and comprehensively enhance engineering quality and efficiency.

2.2. Importance and Common Problems of Slope Protection

The instability of slopes poses a huge threat, which may cause disasters such as landslides and mudslides, resulting in casualties and property losses, damaging the ecological environment, and affecting the operation of engineering facilities. There are problems with current slope protection, with some protection measures designed unreasonably and not fully considering geological and environmental factors. For example, rigid protection for soil slopes is prone to failure due to soil deformation; Poor vegetation growth in vegetation slope protection may be

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due to improper vegetation selection, non-standard planting techniques, or inadequate maintenance in the later stage, as well as insufficient long-term stability monitoring, making it difficult to detect safety hazards. According to incomplete statistics, in some soil slope protection projects, due to the use of rigid protective structures, cracks or even collapse may occur in the protective structure after slight deformation of the soil, resulting in protection failure. In vegetation slope protection projects, due to the mismatch between vegetation selection and local climate and soil conditions, the survival rate of vegetation is low, making it difficult to achieve the expected protective effect.

2.3. Principles and Advantages of Vegetation Slope Protection

Vegetation slope protection is achieved through soil stabilization by root systems and hydrological effects on the aboveground part. The root system interweaves in the soil to form a network, enhancing the shear strength of the soil and improving the stability of the slope; The above ground branches and leaves intercept rainwater, reduce raindrop impact, lower slope runoff velocity, alleviate soil erosion, and regulate soil moisture through vegetation transpiration, improving soil physical and mechanical properties. Compared with traditional engineering slope protection, vegetation slope protection has lower costs, large-scale protection can save material and labor costs, improve ecology, increase biodiversity, promote ecological virtuous cycle, and make the slope natural and beautiful, coordinated with the surrounding environment, and improve the quality of regional landscape. In a cost comparison study for large-scale slope protection, it was found that using vegetation slope protection can save about 20% -30% of material and labor costs per square meter compared to traditional engineering slope protection. At the same time, the number of biological species in the vegetation slope protection area has significantly increased, the ecosystem has become more stable, and the landscape effect has also been widely recognized by surrounding residents.

3. Common Types of Slope Protection Vegetation in Ditch and Land Reclamation

3.1. Herbal Plants

Herbaceous plants grow rapidly and have strong coverage. Although their roots are shallow, they are widely distributed. As a common cold season herbaceous plant, ryegrass is cold resistant and has strong adaptability. It grows quickly and can quickly cover slopes and stabilize soil. It is suitable for cool and humid climates and does not require high soil requirements. Fertile and well drained soil is more conducive to its growth. The sowing rate is generally 20-30 g/m ^{2}, and it is advisable to sow in spring and autumn. Dogtooth root is a representative of warm season type, drought resistant and trampling resistant, with developed root system and strong adhesion to soil. It prefers warm and humid soil and can also grow in dry and barren soil. It can be sown or propagated with roots and rhizomes, with a sowing rate of 10-15 g/m ^{2}. When the roots and rhizomes propagate, they should be cut into sections and spread on the slope surface to compact the soil. Research has shown that on slopes with low soil fertility, ryegrass can form dense vegetation cover in a short period of time through rapid growth and extensive tillering, effectively reducing soil erosion on the slope. Dogtooth roots perform well in slope protection in arid areas, as their developed roots can penetrate deep into the soil to absorb water, maintain plant growth, and play an important role in slope stability.

3.2. Shrubs

Shrubs have well-developed root systems, deep roots, and strong drought, cold, and wind resistance abilities. Purple locust is a common slope protection shrub with root nodules that can fix nitrogen and improve soil. It has dense branches and leaves, good protective effect, and wide adaptability. It can grow in various soils and can also grow normally in mild saline alkali

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soil. It can be sown, cut or transplanted. Sowing is done in spring, and the seeds need to be treated to improve germination rate. Strong branches should be cut into 15-20cm cuttings and inserted into the soil before transplanting. 2-3 year old seedlings with soil balls should be selected before spring germination. Caragana korshinskii has strong drought resistance and is widely used in arid and semi-arid areas. It is suitable for sandy soils in arid and semi-arid regions and is often sown. It is advisable to sow during the rainy season and promote germination before sowing to increase seedling emergence rate.

3.3. Trees

Trees have tall and robust roots, and strong soil fixation ability. Robinia pseudoacacia is a common slope protection tree that grows rapidly and has strong adaptability. It does not have strict soil requirements and prefers light, warm, and humid climates. It can grow in acidic, medium, and alkaline soils. Generally, large seedlings are transplanted, with a diameter of 3-5cm at breast height. They are transplanted in spring and pruned before transplantation to reduce water evaporation and improve survival rate. Ailanthus altissima has strong anti pollution ability and is widely used in slope protection in industrial polluted areas. It has strong adaptability, is resistant to drought and barrenness, and does not have strict requirements for soil acidity and alkalinity. It is also transplanted with large seedlings in spring or autumn, and watered promptly after transplantation to ensure survival. In some mountainous slope protection with acidic soil, Robinia pseudoacacia can quickly root and grow, and its large root system penetrates deep into the soil, effectively enhancing the stability of the slope. In areas with severe industrial pollution, Ailanthus altissima can grow normally in harsh environments due to its anti pollution ability, providing good protection for slopes and absorbing some pollutants from the air to improve the quality of the surrounding environment.

3.4. Vine Plants

Vine plants climb and grow, which can quickly cover slopes and increase vegetation coverage. Climbing ivy is a common vine slope protection plant with dense branches and leaves, fast growth, strong adhesion to slopes, wide adaptability, low soil requirements, and better growth in damp and shady environments. It is propagated by cutting branches into 10-15 cm cuttings and inserting them into the soil to keep the soil moist for rooting and sprouting. Ivy has good shade tolerance and can grow well on slopes with insufficient light. It prefers warm and humid conditions and has strong shade tolerance. It can be propagated by dividing or cutting. In spring, the plants are cut from the roots and planted separately, and semi woody branches are selected for cutting and inserting into loose and breathable substrates. In some damp canyon slopes, ivy can quickly climb and grow, forming a dense vegetation cover layer, effectively reducing rainwater erosion and soil erosion on the slope. Ivy performs well in the greening and protection of slopes with insufficient sunlight in cities. Its beautiful form not only provides protection, but also enhances the urban landscape effect

4. Factors Affecting the Effectiveness of Slope Protection for Different Vegetation Types

4.1. Vegetation Self Factors

The depth, density, and distribution of root systems have a significant impact on slope stability. Deep rooted plants can penetrate deep into the soil to anchor the soil and improve its anti slip ability. A higher root density results in a stronger reinforcement effect on the soil. Trees have deeper and thicker root systems than herbs and shrubs, with outstanding soil fixation ability. The distribution pattern of root systems also affects the protective effect. Wide horizontal distribution enhances the horizontal shear strength of soil, while vertical distribution is more effective in resisting soil sliding force. The height, crown width, and branch and leaf density of

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plants affect slope runoff and rainwater interception. Tall plants and large crown width can effectively intercept raindrops, reduce slope impact, and plants with high branch and leaf density have stronger ability to intercept rainwater, reduce slope runoff velocity and soil erosion. Shrubs have denser branches and leaves than herbs, and are more effective in intercepting rainwater and reducing slope runoff. Reasonable plant morphology can also reduce wind speed and wind erosion on slopes.

4.2. Soil Conditions

Different soil textures have a significant impact on vegetation growth and protection effectiveness. Sand soil has good ventilation but poor water and fertilizer retention, which is not conducive to long-term vegetation growth. Planting on sandy slopes requires water and fertilizer retention; The soil texture is moderate, with good ventilation, water retention, and fertility, suitable for most vegetation. The vegetation slope protection effect of the soil slope is relatively good; Clay has strong water and fertilizer retention but poor ventilation, which can easily cause vegetation root hypoxia. In clay slopes, it is necessary to improve soil ventilation and choose vegetation types that are suitable for the clay environment. Soil fertility includes nutrient content, acidity, etc. Adequate nutrients are the foundation of vegetation growth, and major nutrients such as nitrogen, phosphorus, and potassium directly affect the growth rate and health status of vegetation. Soil acidity affects vegetation growth, and different vegetation have different adaptation ranges. Acidic vegetation grows poorly in alkaline soil, while salt tolerant vegetation can grow normally in alkaline soil. Slope protection requires selecting vegetation according to soil fertility and fertilizing to improve fertility.

4.3. Climate Conditions

The intensity, frequency, and total amount of precipitation have a significant impact on slope erosion and vegetation growth. Heavy precipitation causes a rapid increase in slope runoff, which enhances the erosion force on the slope and easily leads to soil erosion and slope instability. Frequent precipitation can result in high soil moisture content, affecting vegetation root respiration and growth. Moderate precipitation is beneficial for vegetation growth and provides water. In areas with abundant precipitation, water resistant vegetation should be selected and slope drainage should be strengthened; In arid areas, drought tolerant vegetation should be selected and water-saving irrigation should be adopted. Temperature affects the growth cycle and stress resistance of vegetation. Suitable temperature is beneficial for vegetation growth and development, while too high or too low temperature can have adverse effects on vegetation. Cold resistant vegetation in cold regions may suffer from freezing damage, affecting the effectiveness of slope protection. Vegetation in high temperature regions may face drought stress and intensified pest infestations. When selecting vegetation, local temperature conditions should be fully considered.

4.4. Slope Characteristics

Slope has a significant impact on the difficulty of vegetation planting, growth status, and slope protection effect. The steeper the slope, the more difficult it is to plant vegetation, the faster the runoff speed on the slope, the stronger the erosion force on the slope, and the greater the impact on vegetation growth. The root system of vegetation on steep slopes is difficult to root and stabilize, and is prone to death due to soil erosion. Gentle slopes are more conducive to vegetation growth and slope protection effects. Different slope degrees require the selection of appropriate vegetation types and planting methods. For example, steep slopes can be sprayed with nets. The slope orientation affects the conditions of light and moisture, which in turn affects vegetation growth and slope protection effectiveness. The sunny slope has sufficient light and high temperature, but water evaporates quickly and the soil moisture content is relatively low, making it suitable for planting light tolerant and drought tolerant vegetation.

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The shady slope has insufficient light and low temperature, but good moisture conditions, making it suitable for planting shade tolerant and moisture tolerant vegetation.

5. Strategies and Suggestions for Improving the Effectiveness of Slope Protection

5.1. Scientific Selection of Vegetation Types

Select plants accurately based on local natural conditions. Choose drought tolerant vegetation in arid areas, such as lemon shoots, which have well-developed root systems and can take root and solidify soil in areas with annual precipitation of less than 200 millimeters, resisting sandstorms. Choose acid loving vegetation in acidic soil areas, such as rhododendrons, whose shallow dense root system can stabilize shallow soil and reduce erosion. Choose vegetation with developed root systems and strong soil stabilization on steep slopes, such as Robinia pseudoacacia, which can penetrate deep into the soil and enhance slope stability. Pay attention to the coordinated combination of vegetation and adopt a combination of trees, shrubs, and grasses. Taking the slope protection of the Loess Plateau as an example, Robinia pseudoacacia anchors deep soil layers, Robinia pseudoacacia reinforces shallow layers and intercepts runoff, and dogtooth roots quickly cover the slope surface, jointly improving protection and ecological stability.

5.2. Optimizing Vegetation Configuration Mode

Build a protective structure through layered configuration. Planting tall trees such as poplar trees on the upper layer of the slope, with their tall trunks reducing wind speed and deep roots enhancing soil resistance to sliding; Middle level shrubs such as purple locust trees, whose rhizobia fix nitrogen to improve soil, intercept rainwater and reduce runoff velocity through their branches and leaves; Planting grass such as ryegrass in the lower layer, quickly covering the slope surface, and stabilizing the soil and slope protection in the early stage. Promote mixed planting to increase vegetation diversity. Mix leguminous and non leguminous plants, such as alfalfa and dogtooth root. Alfalfa rhizobia fix nitrogen to improve soil fertility, promote the growth of dogtooth roots, enhance soil stability with different root distribution, and improve slope protection effectiveness.

5.3. Strengthen Post Maintenance Management

Reasonably irrigate and fertilize according to vegetation requirements and soil moisture. Irrigation should be carried out in a timely manner during the dry and dry seasons. Herbs should be irrigated 1-2 times a week until the soil is 10-20 centimeters moist; Shrubs and trees should be planted once every 1-2 weeks. Apply organic fertilizer in spring and autumn, 1000-2000 kilograms per mu, to improve soil structure; Apply nitrogen, phosphorus, and potassium fertilizers during the peak growth period, with a dosage of 20-50 kilograms per mu, to promote the development of branches, leaves, and roots. Comprehensive prevention and control of pests and diseases. Biological control utilizes ladybugs to control aphids and other natural enemies; Using black light lamps for physical control to trap nocturnal pests, yellow board aphids, etc; When pests and diseases are severe, use highly efficient, low toxicity, and low residue pesticides for chemical control, conduct regular inspections, timely prevention and control, and ensure the effectiveness of slope protection.

6. Conclusion and Prospect

This study summarizes the overview of ditch and land reclamation engineering and slope protection, introduces common types and characteristics of slope protection vegetation, their adaptability to the environment, and planting points. It analyzes the influencing factors of slope

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protection effects of different vegetation types and proposes strategic suggestions to improve protection effects. Different vegetation types have their own advantages in slope protection. By scientifically selecting vegetation, optimizing configuration, and strengthening maintenance management, the effectiveness of slope protection can be effectively improved. There are limitations in the research, as there is insufficient long-term monitoring data on the protective effects of different vegetation types, and regional adaptability research is not comprehensive enough. In the future, it is necessary to strengthen long-term monitoring, establish vegetation slope protection databases in different regions, conduct in-depth research on regional adaptability, and combine new technologies such as unmanned aerial vehicle monitoring and intelligent irrigation to enhance the scientific and intelligent level of slope protection.

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