



Discussion on Ecological Restoration Strategies for Karst Rocky Desertification in Guilin, Guangxi

Yishuai Zhang

College of Tourism and Landscape Architecture, Guilin University of Technology, Guangxi
Zhuang Autonomous Region, Guilin, 541006 China

530411370@qq.com

Abstract. Karst rocky desertification in Guilin is a serious ecological problem caused by the combined effects of natural geological fragility and human activities, manifested by aggravated soil erosion, vegetation degradation, water resource shortages, etc., which restricts regional sustainable development. Based on the current status and control practices of rocky desertification in Guilin, this paper systematically analyzes existing measures, including optimized allocation of water resources, combination of closed afforestation and artificial afforestation, and eco-agricultural models. The study shows that although phased achievements have been made, challenges remain such as insufficient stability of restoration outcomes, poor technical adaptability, and single ecosystem service functions. To address these issues, improvement strategies are proposed: emphasizing regional integrated management and systematic restoration, promoting the integrated protection and restoration of mountains, rivers, forests, farmlands, lakes, and grasslands; exploring mechanisms for realizing the value of ecological products and developing eco-tourism and characteristic industries; improving vertical and horizontal ecological compensation systems; and promoting social-ecological system synergy by optimizing population and industrial. Through refined zoning management and sustainable restoration, this study can provide scientific and technological support for rocky desertification control in Guilin and other karst areas of Southwest China.

Keywords: Guilin; Karst; Rocky Desertification; Ecological Restoration; Management Strategies

1 Introduction

Land rocky desertification in karst areas is mainly caused by the fragile environmental geological conditions and inappropriate human economic activities. The fragile ecology and geological environment of karst areas are the basic conditions for land rocky desertification. Meanwhile, the warm and humid monsoon climate provides the necessary dissolution environment for the intense formation of karst landforms. Among them, population pressure is a key factor driving the rocky desertification process.

Rocky desertification significantly deteriorates the ecological and natural environment in karst areas. Particularly severe are soil erosion and degradation, intensified water and soil loss, and reduction of arable land [1]. Moreover, the retrogressive succession of vegetation reduces plant species and biomass in the karst ecosystem, simplifies vegetation structure, and weakens species diversity. Reduced vegetation coverage leads to bare rock surface and decreased forest vegetation, further exacerbating ecological degradation. As the most prominent ecological and environmental problem in Southwest China's karst region, rocky desertification not only endangers the ecological security of the upper reaches of the Yangtze River and the Pearl River basin, but also restricts local economic development and intensifies the contradiction between humans and nature.

2 Current Status of Rocky Desertification in Guilin

Guilin is located in the northeastern part of Guangxi Zhuang Autonomous Region, covering about 11% of the total area of Guangxi. Its longitude ranges from 109°36'50" to 111°29'30" E, and latitude from 24°15'23" to 26°23'30" N. The city has a subtropical monsoon climate, characterized by abundant rainfall, with an average of 166 rainy days per year, annual precipitation of 1887.6 mm, and average annual relative humidity of 76%. In addition, Guilin has a mild climate, short frost period, sufficient sunshine, and abundant heat resources, with an average annual temperature of about 9°C. The rainy season coincides with the hot season, with long summers and short winters, providing a favorable environment for plant growth.

Because Guilin is subject to intense rainfall and runoff, soil erosion is extremely significant especially on bare rocky desertification land without vegetation cover. At the same time, due to the poor water conservation capacity in karst areas, surface water easily leaks into the ground through karst fissures, causing depletion of available water resources. This scarcity of water and soil resources is a distinctive feature of karst areas, further exacerbating the frequent occurrence of droughts and floods.

Guilin is located southwest of the Nanling Mountains, in the northern-central part of the Guilin-Yangshuo karst basin, at the border between Hunan and Guangxi. The topography is mainly medium or low mountain landforms, with peak elevations ranging from 97 to 2141 m. The topographic features show higher terrain in the west, north, and southeast, and relatively lower in the central part. The eastern and western sides are low mountains and hills, the northern and southern ends are gentle hills, and the central part presents typical karst landforms, forming a cityscape surrounded by mountains and green water. Soils in Guilin's karst areas are mainly residues from the dissolution of carbonate rocks, also called limestone soils. The pH of these soils ranges from 4 to 8, indicating a slightly acidic to neutral range. Due to karst processes, the soil structure is relatively loose with high porosity, resulting in serious water and soil loss and soil erosion, weak water storage capacity, and low soil moisture content.

3 Current Status of Rocky Desertification Control in Guilin

3.1 Rocky Desertification Control Measures

3.1.1 Developing Water Resources According to Local Conditions To effectively develop and utilize karst water resources and improve the ecological environment in karst areas, Guilin has adopted a series of practical measures based on its specific natural conditions and agricultural needs. The average annual rainfall in Guilin exceeds 1000 mm, but precipitation is mainly concentrated in late spring and early summer, while droughts often occur in early autumn and early spring when crops are growing vigorously. The city has fully utilized the characteristic that surface water in karst areas easily converts to groundwater, forming underground runoff to regulate uneven precipitation.

For this purpose, Guilin has implemented reinforcement projects for dangerous reservoirs to ensure safety and increase storage capacity; promoted water-saving irrigation methods to improve water use efficiency; and carried out small watershed management projects to store more surface water for irrigation and domestic use during dry seasons through rational allocation and regulation of water resources.

In addition, to optimize water resource distribution, Guilin has built canals to divert water from water-rich areas to water-scarce areas, ensuring the production and domestic water needs of the whole city. These measures not only help improve the ecological environment in karst areas but also provide strong support for Guilin's sustainable development.

3.1.2 Comprehensive Vegetation Restoration Models. In the karst areas of Guilin, comprehensive implementation models such as closed afforestation, artificially assisted vegetation restoration, and artificial afforestation have been adopted according to the specific natural conditions of rocky desertification land. These models aim to efficiently utilize local light, heat, and water resources, with even small pieces of land in karst fissures being used for tree planting. This approach effectively reduces temperature differences and water evaporation on rock surfaces, improves local microclimate conditions, and thereby slows the rocky desertification process.

In the process of rocky desertification control in Guilin's karst areas, in addition to the above comprehensive models, special attention has been paid to the scientific planning and precise implementation of ecological engineering. To ensure the durability and stability of vegetation restoration, a variety of drought-tolerant and barren-tolerant tree species, such as oaks and cypresses, have been introduced. These species can grow tenaciously in rock crevices, not only enriching local plant diversity but also adding stability to the ecosystem.

During the control process, Guilin has paid special attention to ecosystem connectivity. By constructing ecological corridors and restoring wetlands, scattered vegetation patches have been connected to form a complete ecosystem network. This is beneficial

for species migration and reproduction, as well as improving ecosystem stability and resilience.

As control efforts advance, the ecological environment in Guilin's karst areas has significantly improved. Lands that were once bare rock are gradually covered by lush trees, and originally dry, barren lands have become vibrant. The local microclimate has also markedly improved, with reduced temperature differences and less water evaporation, providing a more livable environment for residents. Meanwhile, vegetation restoration has driven the development of local eco-tourism, injecting new vitality into the local economy.

3.1.3 Eco-Agriculture Development. Eco-agriculture refers to an agricultural development approach that, on the basis of maintaining and improving the agricultural ecological environment, applies ecological and eco-economic principles, uses systems engineering methods and modern technology, and implements intensive management. Its development aims to promote the protection and improvement of the ecological environment, control pollution, maintain ecological balance, and thereby enhance ecosystem stability and sustainability. Guilin has established a "livestock-biogas-planting" integrated model. Relying on the bridging role of biogas construction, it has achieved mutual promotion between animal husbandry and biogas, while biogas slurry and residues effectively support the development of planting industries.

Guilin, characterized by significant mountainous and hilly terrain, has inherent advantages for developing three-dimensional eco-agriculture. However, if ecological balance is ignored and fruit trees are continuously planted on hillsides blindly, it will lead to serious ecological and environmental problems, especially the further aggravation of land rocky desertification. Therefore, Guilin has followed its existing eco-agriculture development model, continuously broadening ideas, improving production efficiency, and expanding comprehensive benefits, thereby building a comprehensive, three-dimensional eco-agricultural structure described as "wearing a hat, tying a belt, and putting on boots." Specifically, on bare rock and difficult-to-cultivate areas with slopes exceeding 35°, closed afforestation is implemented to restore vegetation; on slopes between 25° and 35°, economic trees are planted to achieve both economic and ecological protection goals; and on gentle slopes below 25°, economic crops are planted to fully utilize land resources and promote sustainable agricultural development.

In the process of continuous agricultural economic development, a series of new environmental problems have emerged. Especially in mountainous areas, farmers often clear shrubs and weeds under trees to plant fruit trees, leaving the surface bare and without vegetation protection. This situation easily causes soil erosion, further reduces soil fertility, thins the soil layer, and gradually degrades vegetation. In karst areas, where the soil layer is already thin, barren, and scattered mainly in stone crevices or karst fissures, soil erosion accelerates the land rocky desertification process.

To address these environmental problems, the government has banned deforestation to protect water sources [2]. Also, to reduce the damage caused by goats to vegetation, it is stipulated that goats must be kept in enclosures and not allowed to graze freely. Goats are extremely destructive to vegetation, and plants they browse cannot recover

quickly. Furthermore, strictly following relevant regulations, cultivation on slopes exceeding 25 degrees is prohibited. For areas already cultivated on such steep slopes, it is required that, on the basis of constructing basic farmland, according to specific conditions, gradually implement returning farmland to forestry, planting trees and grass to restore vegetation, or build terraces to ensure sustainable use of land resources.

Currently, the challenges encountered in rocky desertification control in China are mainly reflected in the insufficient stability of restoration outcomes, difficulty in resolving the human-land contradiction, and increasing management difficulty [3]. Against the backdrop of implementing a series of karst ecological protection and restoration projects, the trend of rocky desertification development has shown positive changes, manifested as continuously shrinking areas of rocky desertification and significantly reduced intensity. Given that initial results have been achieved in ecological improvement in rocky desertification areas, how to further enhance the quality and durability of ecological restoration and strengthen ecosystem service capacity has become a new task and requirement for ecological restoration in karst areas [4].

3.2 Challenges and Issues

In recent years, scholars have proposed various models for rocky desertification control. However, the sustainability and targeting of these models and their technologies are still insufficient. Given the unique geological structure of karst areas, the control technologies and models currently adopted by researchers are mostly based on experiences from southern mountainous areas and the Loess Plateau, such as planting hedgerows, building retaining walls, and contour terracing. They fail to deeply analyze the particularities of water and soil movement under the dual hydrological structure of karst areas, making it difficult to achieve expected results in practice. Moreover, current technologies and models also lack adequate consideration of adaptability issues.

Under the background of large-scale afforestation and natural restoration, although large contiguous plantations have been successfully formed, the recovery of key ecological service functions such as soil retention and water conservation has been relatively lagging, exposing problems such as single ecological service functions and insufficient sustainability. In addition, in promoting poverty alleviation and development of characteristic industries, some areas have developed economic forests and fruits, understory planting, and animal husbandry, leading to new local rocky desertification problems. Therefore, there is an urgent need to conduct in-depth research on the impacts of different restoration measures on ecosystem service functions and related enhancement technologies, providing a solid scientific basis for the sustainability of ecological restoration and poverty alleviation, ensuring that Guilin's rocky desertification ecological restoration measures are more reasonable and adapted to local conditions.

The focus of rocky desertification control work should be on in-depth study of natural ecosystems and exploration of the relative contributions of different natural factors and socio-human factors to regional ecological restoration. In the process of ecological restoration in karst areas, national ecological protection and construction strategies play a core guiding role. Meanwhile, with the increase in migrant workers, rapid urbanization, and gradual improvement of poverty, the direct pressure of population on land

resources has been effectively alleviated, further promoting the regional ecological restoration process.

Currently, the field of rocky desertification control faces a major technological challenge: how to scientifically analyze the rapid reduction process and mechanisms of rocky desertification recovery, as well as the complex feedback mechanisms between ecological and social systems. This challenge requires us to accurately distinguish the relative roles of natural factors and socio-human processes in regional ecological restoration, and on this basis, rationally optimize future ecological construction layouts.

Given the significant increasing trend in vegetation coverage, the current rocky desertification control work is ushering in a critical transition period. We need to transform relatively extensive control measures into refined zoning management and protection strategies, and upgrade from single-ecosystem-scale restoration and demonstration models to regional-scale integrated protection, systematic restoration, and comprehensive management. To this end, a systematic plan has been proposed to improve the efficiency and quality of rocky desertification control and achieve sustainable ecological restoration. This plan will provide certain scientific and technological support for the optimization of subsequent rocky desertification control projects.

4 Suggestions and Improvement Strategies

In view of the current problems in rocky desertification control in Southwest China, such as insufficient attention to sustainability, ecosystem service functions, and socio-human processes, future karst rocky desertification control in Southwest China should focus on regional integrated management and green development. Specific counter-measures and suggestions include the following four aspects(Fig.1):

(1) Emphasize regional integrated management and systematic restoration

In recent years, the development trend of rocky desertification in China has been effectively curbed, and phased results have been achieved. At present, the focus of rocky desertification control should be on consolidation and improvement, with timely adjustments to the priorities and directions of rocky desertification control [5]. Shift from relatively extensive control measures to refined zoning management and protection, adopt integrated management approaches, formulate systematic plans for improving quality and efficiency of rocky desertification control and sustainable ecological restoration, and adhere to the path of high-quality green development. At this stage, while focusing on small watershed management, attention should also be paid to regional integrated management and green development. Carry out large-scale transformation and reconstruction of low-efficiency plantations, quality improvement of hillside shrub forests at karst foothills, under-canopy afforestation, screening of eco-economic forest and grass species, development of understory economy and characteristic economic forest, fruit, and medicine industries, and expand ways for sustainable utilization of land resources in rocky desertification areas and conservation of karst landscape resources. Build national karst parks, and promote the integrated protection and restoration of mountains, rivers, forests, farmlands, lakes, and grasslands in karst rocky desertification areas.

(2) Explore mechanisms and pathways for realizing the value of karst ecological products

The realization of ecological product value aims to achieve a harmonious unity of ecological, social, and economic benefits. Establishing a government-led, multi-participant, sustainable, and market-oriented value realization mechanism is a key measure to implement the thought of ecological civilization and adhere to green development and ecological priority. Ecological products, as public goods, have multiple functions such as providing livable spaces, regulating ecological functions, and maintaining ecological security. The pathways for realizing their value include market pathways, government pathways, and mixed market-government pathways. Market pathways realize the conversion of ecological product value through market allocation and transactions; government pathways mainly rely on government procurement and transfer payments; and mixed pathways cultivate and develop trading entities for ecological products through financial support, administrative control, and even legal means, supporting related trading activities so that ecological products can demonstrate their unique value.

The realization of ecological product value is inseparable from natural resources as an important carrier. Natural resources provide necessary support and guarantee for the realization of ecological product value in terms of space and materials. For damaged karst areas, through the restoration, management, and comprehensive development of natural ecosystems, the aim is to restore and enhance ecosystem functions such as biodiversity protection, water conservation, carbon sequestration and oxygen release, and recreation [6]. On this basis, explore and support innovative development models for eco-tourism, animal husbandry, and agriculture and forestry, build a scientific system for science and technology poverty alleviation, and promote industrial integration through vegetation mixed management. At the same time, scientifically protect and utilize karst geological landscapes such as caves, tiankengs, canyons, and wetlands. While ensuring their integrity, carefully create karst landscape scenic areas, scientifically plan and moderately develop tourism. These measures aim to effectively protect and restore ecology, efficiently supply ecological products, form a scientific mechanism for realizing ecological product value, both increase farmers' income and steadily solve poverty problems.

(3) Strengthen ecological compensation in karst areas

The core value of public ecological products provided by government departments is realized through the ecological compensation mechanism, which plays a crucial role in coordinating the interests between ecological beneficiaries and protectors [7]. Currently, the main means of ecological compensation in China is vertical transfer payments, through which higher-level governments provide financial support to lower-level governments to achieve ecological compensation goals. Horizontally, China generally implements horizontal ecological protection compensation models within provinces (autonomous regions, municipalities) or across provincial boundaries for upstream and downstream areas of rivers. However, it must be pointed out that the ecological compensation mechanism for ecologically fragile areas is still in the preliminary exploration stage. To build a more efficient and scientific ecological compensation system, China should actively promote the introduction of market mechanisms, facilitate the coordinated management of funds across fields and levels, and encourage the broad

participation of social capital, leveraging their advantages in management and technology to help achieve more significant results in China's ecological compensation work.

(4) Explore synergistic mechanisms of social-ecological systems in karst areas

With the steady advancement of urbanization and increased off-farm employment, population pressure has been significantly alleviated, and rural residents' dependence on land resources has correspondingly decreased, providing favorable conditions for the protection and restoration of karst ecosystems. However, along with large-scale population migration and movement, the permanent population in rocky desertification areas has significantly decreased, and karst areas, especially rural communities, face severe challenges of hollowing out or even abandonment. At the same time, the shift of rural labor to non-agricultural sectors is prominent, and problems of aging population and weakening labor force are increasingly serious.

Therefore, to achieve harmony between population and living space, environmental capacity, ecological carrying capacity, and economic development, it is necessary to moderately regulate population and rationally guide population transfer [8]. On this basis, given the diversity and fragility of karst ecosystems, while developing industrial economy, emphasis must be placed on ecosystem protection, with scientific optimization of industrial structure and layout. At the same time, fully utilize the resource advantages of different regions, actively develop ecological agriculture and green industries, and build industrial clusters with local characteristics to achieve sustainable development.

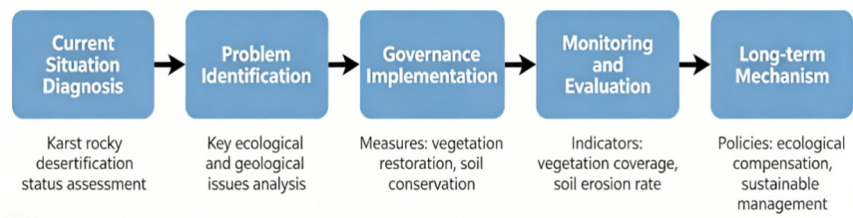


Fig. 1. Planning of Protection and Restoration Process for Karst Rocky Desertification in Guilin

5 Conclusion

Land rocky desertification is a major ecological challenge in karst areas. Its formation is influenced and constrained by multiple factors, among which human activities are particularly significant. This phenomenon not only severely damages the ecological environment and intensifies the tension in human-land relationships, but also continuously erodes precious land resources, posing a serious threat to the survival of residents in karst areas. Therefore, in solving the problem of rocky desertification in karst areas, the key is to enhance people's ecological and environmental awareness, actively promote the development of eco-agriculture, thereby reducing inappropriate interference

with the environment, achieving the goals of preventing land rocky desertification and restoring ecological balance.

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