Research on the Causes and Countermeasures of Soil Erosion in Small Watersheds of Chengjiang River in Gongcheng County

Zhanfei Gu1,2,3,a, Zhikui Liu1,2,3,b* and Xin Quan1,c
1College of Civil Engineering and Architecture, Guilin University of Technology, Guilin, Guangxi 541004, China;
2Key Laboratory of Guangxi Geotechnical and Engineering, Guilin, Guangxi 541004, China;
3Technical Innovation Center of Mine Geological Environmental Restoration Engineering in Southern Area, Nanning, Guangxi 530029, China.
*aemail: guzhanfei2005@163.com, bemail: 1998009@glut.edu.cn, cemail: 215597847@qq.com,
*Corresponding author’s e-mail: 1998009@glut.edu.cn

Abstract. Rocky desertification induced by soil erosion is a serious geological hazard in the karst regions of southwestern China. This paper made a research on small watersheds of Chengjiang River in Gongcheng County, Guilin City, Guangxi Province, analyzed the causes and trends of soil erosion in the regions by comparing rocky desertification areas in 1991, 2006 and 2015, and proposed countermeasures against soil erosion based on the above analysis. This research provides a basis for restoring ecological environments and preventing soil erosion in small watersheds of karst regions.

1. Introduction

Soil erosion is a major geological disaster in karst regions of southwest China. It covers a large of land and a number of regions, and many regions are in severe situation. Furthermore, the causes of soil erosion are complex and regional differences are obvious[1]. Statistics showed that the total area of soil erosion in China is around 3.56 million km², accounting for 37% of the total land area, of which the area of water erosion is 1.65 million km² and that of wind erosion is 1.91 million km². Guangxi Zhuang Autonomous Region is one of the regions that experience severe soil erosion and rocky desertification caused by that [2-3].

Gongcheng Yao Autonomous County enjoys a complex topography, which is characterized by a lot of steep mountains and a great number of widely distributed rivers. Also, the most rains falls from June to September. These factors combined to cause severe soil erosion in the county. This paper analyzed the status, characteristics and causes of soil erosion in Gongcheng County, summarized the problems and trends in soil erosion control, and proposed countermeasures and suggestions. Therefore, this research is of great significance in restoring ecological environments in small watersheds.
2. Geography of Gongcheng Yao Autonomous County

Gongcheng Yao Autonomous County (24°37′-25°17′N, 110°36′-111°10′E) is located in the southeast of Guilin or northeast of Guangxi Zhuang Autonomous Region, bordering Fuchuan Yao Autonomous County of Hezhou City and Jiangyong County of Yongzhou City to the east, Zhongshan County of Hezhou City and Pingle County of Guilin City to the south, Yangshou County and Lingchuan County of Guilin City to the west, and Guanyang County of Guilin City to the north. Gongcheng towns are 108 kilometers from Guilin City. The county is embraced on the east, west and north sides by middle-low mountains, a valley corridor runs from north to south in the middle, mountains and hills dominate within the county, and small flat lands are distributed along rivers. The climate of Gongcheng is subtropical monsoon climate with four distinct seasons, summers are humid and long, while winters are dry and short. The county also receives adequate light and abundant rainfall. There are 318 peaks higher than 1000 meters above sea level, Yindian mountain is the highest mountain in Gongcheng with a main peak of 1885 meters. Gongcheng River (Cha River) runs through the county with tributaries densely distributed. The climate in Gongcheng is mild, the average annual temperature is 19.7℃, and the average annual rainfall is 1,437mm.

3. Status and analysis of soil erosion in small watersheds of Chengjiang River

The main cause of soil erosion in the Chengjiang small watershed in Gongcheng County is that a large area of karst landscape and rocky desertification region span in the county. Rocky desertification refers to the phenomenon that a karst area covered by vegetation is transformed into rocky landscape as a result of human activities [4-5]. Karst rocky desertification is caused by surface exposure due to wasteland clearing on steep slopes and forest vegetation deterioration at the beginning, which is a result of long-term human activities. The thin soil layer of karst rocky areas is then washed away by rainstorms and basement rocks are exposed. Soil erosion occurs because of surface runoff erosion and karst erosion, and severe soil erosion further causes rock exposure. Rocky desertification then occurs in some areas and aggravates soil erosion in turn. Remote sensing data shows that the areas of karst rocky desertification in Chengjiang small watersheds of Gongcheng County are 160.8km² in 1991, 118km² in 2006 and 253km² in 2015, accounting for 7.5%, 5.5% and 11.8% of the total land area respectively. Karst rocky desertification has been a major geological hazard that restricts the economic development of local regions [6-7].

Through field investigation in Chengjiang small watersheds of Gongcheng County, it was found that although fruit trees and other plants are planted on hillsides to control rocky desertification, serious rocky desertification and soil erosion problems still exist in this area. As figure 1 shows, fruit trees and other plants are planted at the feet, on the hillsides and on the hilltops of the mountains, but soil erosion situation is still rigorous.

![Fig. 1 Landscape and soil erosion in Chengjiang small watersheds](image)
4. Causes of soil erosion in Chengjiang small watersheds

4.1. Natural factors

Gongcheng is a county with typical karst landform area. It is embraced on the east, west and north sides by middle-low mountains, and a valley corridor runs through the county from south to north. Most of its terrain is made up of peak-cluster depressions, peak forest valleys and karst valleys, in which river valleys, flat lands, terraces and hills intersect each other. Rocky desertification occurs mainly in karst valleys, which are distributed in the middle of the county and are 150-500 meters above sea level. Rainfalls in springs and summers account for more than 90% of the annual precipitation. Seasonal drought problem is then caused by the uneven distribution of precipitation. Pure carbonate rocks are widely distributed in Karst areas. Under natural conditions, the dissoluble components in carbonate rocks will be dissolved and washed away, and those insoluble components will be transformed into soil. Since carbonate rocks are mainly composed of dissoluble components, thus most of the rocks are dissolved and washed away, and thus the process of rock weathering is very slow. In addition, strong geological tectonic movements lead to a number of cracks, joints and faults in carbonate rocks. Water flow will preferentially pass through these weak parts, expanding the fracture, and eventually resulting in sinkholes, karst fensters, avens, karst caves, underground rivers, etc. Thus the unique double layer structure, an aboveground layer and an underground layer, is formed. Surface water runs through the thin layer of soil and rocks and quickly moves into sinkholes or avens. In this case, water runs off from both the surface and underground. The more dissoluble components in the rock, the stronger is tectonic activity, and the faster is carbonate dissolution and soil weathering. However, the water storage capacity in the area will become lower, soil erosion is aggravated and ecosystem becomes increasingly fragile [8].

The soil profile in the karst mountainous area lacks the parent material layer, in other words, the surface soil and matrix carbonate rocks directly contact with each other without transition layer, and the interfaces between soft layer and hard layer are obviously different, which greatly reduces the adhesion and affinity between rocks and soil. Therefore, soil erosion can occur easily when raining.

4.2. Human factors

The landscape of Gongcheng County is mainly karst area. Although the geological conditions are not favorable, the precipitation and temperature conditions are good in subtropical monsoon climate, which is conductive to the growth of plants. Most plants with tenacious vitality can adapt to local conditions. Actually, human activities are the main cause of rocky desertification. The impact of human activities on rocky desertification is mainly manifested in three aspects: vegetation damage, irrational farming system and mining.

Vegetation deterioration: Vegetation deterioration in karst regions of southwestern China is caused by multiple factors. Firstly, those regions abound with mountains and hills and lack plains; secondly, the regions have large agricultural population and population density is high, people have to destroy forests to reclaim wasteland and farm on steep slopes; thirdly, farming methods are backward and there is no alternative industry. Vegetation deterioration further accelerates soil erosion when raining, and rocky desertification occurs. Thus, those regions fall into a vicious cycle of soil erosion-rocky desertification-soil erosion.

Irrational farming system: Local people would reclaim wastelands and abandon them when the soil loses its fertility, because they have weak awareness of environmental protection and lack of scientific farming modes. In this case, both vegetation and sources of forest and vegetation are destroyed, which further intensifies soil erosion.

Mining: Excessive mining will destroy the ecological balance of biological community and affect water resources and water cycle. The surface structure of mining areas will be destroyed in excessive exploitation, and land subsidence and cracks will form. In this case, water resources, water cycle, aquifer level and groundwater quality will be seriously damaged.

In general, soil erosion in karst areas is the result of both geological factors and human activities,
leading to vegetation deterioration, rocky desertification over time, and ultimately more serious soil erosion.

5. Countermeasures against soil erosion

5.1. Protect native plants and grow suitable plants
The old practice of destroying native plants and growing new plants should be abandoned, because the soil layers of Gongcheng's mountainous areas are thin and poor. It is also not suggested to plant traditional crops with low survival rate such as sweet potatoes and corns, since it makes no contribution to the rapid development of the local economy and society. Through field investigations, it is found that the soil of the karst regions in Gongcheng County is thin, neutral or alkaline, and low in nutrients. Although the annual rainfall is relatively high and the climate is relatively humid, there is less surface water and abundant groundwater due to its poor water storage capacity. Taking account of all these conditions, it is suggested to protect native plants and growing winged wood and teak trees. These plants can help alleviate rocky desertification and reduce soil erosion to some extent.

5.2. Rational mining
Carry out special rectification activities and improve supervision and management continuously. Improve and rectify mineral resource development and utilization, crack down heavily on illegal occupation of forest land in the name of mining, shut down and eliminate some mines with problems of low production capacity, environmental pollution and soil erosion gradually, eradicate unauthorized mining step by step. Vigorously publicize the importance of canonical mining and laws and rules relating to mine exploitation and vegetation protection. Improve the legal awareness of citizens and mine owners on mining, forest land utilization and vegetation protection in accordance with the law.

5.3. Change irrational farming system
Strengthen education and publicity on soil erosion control for local villagers, raise their attention on soil erosion control, and avoid the cycle of wasteland reclaiming and abandoning. Establish a monitoring system for soil and water conservation, and measure soil erosion loss regularly. Enhance publicity on water and soil conservation for local citizens, raise their awareness of soil protection, and strive to realize ecological restoration and high-quality development of local economy and society.

Acknowledgements:
This research was funded by the National Natural Science Foundation of China (Grant No. 41867039), and the Natural Science Foundation of Guangxi (Grant No. 2017GXNSFAA198238), and the Foundation of Technical Innovation Center of Mine Geological Environmental Restoration Engineering in Southern Area(Grant No. CXZX120201002). The authors also thank the reviews for their constructive suggestions and comments on the article.

References
[1] DX Yuan, DH Zhu, JT Weng, et al. (1994). Karst of China[M]. Beijing: Geological Publishing House.
[2] ZC Jiang, WQ Luo, LQ Tong, et al. (2016). Evolution features of rocky desertification and influence factors in karst areas of southwest China in the 21st century[J]. Carsologica sinica, 35(5), 461-468.
[3] GY An, X Zhou, J Wen, LQ Tong. (2016). Analysis of Characteristics and Reason of Rocky Desertification Occurrence and Evolution in Karst Areas of Southwestern China[J]. Geoscience, 30(5), 1150-1159.
[4] YB Li, J Huang, Q Xu, JG Luo. (2017). Rethinking the concept and restoration of Karst rocky desertification [J]. Journal of Guizhou Normal University(Natural Sciences), 30(5), 1-6.
[5] MM Wang, SJ Wang, XY Bai, et al. (2019). Evolution characteristics of karst rocky desertification
in typical small watershed and the key characterization factor and driving factor[J]. Acta Ecologica Sinica, 39(6), 6083-6097.

[6] YH Yao, DZ Suonan, JY Zhang, et al. (2019). Spatiotemporal characteristics of karst rocky desertification and the impact of human activities from 2010 to 2015 in Guanling County, Guizhou Province[J]. Progress in Geography, 38(11), 1759-1769.

[7] YB Li, SS Li, Q Xu, et al. (2019). The evolution of karst rocky desertification for nearly 50 years in karst mountain, Southwest China based on five cases study[J]. Acta Ecologica Sinica, 39(22), 8526-8538.

[8] Q Li, JB Pu, N Huang, et al. (2017). A Research Approach for Ecological, Environmental and Geological Differentiation of Rocky Desertification and Its Driving Mechanism in Karst Graben Basin[J]. Advances in Earth Sciences, 32(9), 899-907.