

Rocky desertification control in Karst areas in Southwest China

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This discussion paper is/has been under review for the journal Solid Earth (SE).
Please refer to the corresponding final paper in SE if available.

The challenge and future of rocky desertification control in Karst areas in Southwest China

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Received: 2 November 2015 – Accepted: 3 November 2015 – Published: 20 November 2015

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Published by Copernicus Publications on behalf of the European Geosciences Union.

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Abstract

Karst rocky desertification occurs after vegetation deteriorates as a result of intensive land use, which leads to severe water loss and soil erosion and exposes basement rocks, creating a rocky landscape. The karst rocky desertification is found in humid areas in Southwest China, the region most seriously affected by rocky desertification in the world. In order to promote ecological restoration and help peasants out of poverty, the Chinese government carried out the first phase of a rocky desertification control project from 2006 to 2015, which initially contained the expansion of rocky desertification. Currently, the Chinese government is prepared to implement the second phase of the rocky desertification control project, and therefore it is essential to summarize the lessons learned over the last ten years of the first phase. In this paper, we analyze the driving social and economic factors behind rocky desertification, summarize the scientific research on rocky desertification in the region, and finally identify the main problems facing rocky desertification control. In addition, we put forward several policy suggestions that take into account the perspective of local peasants, the scientific research, and China's economic development and urbanization process. These suggestions include: promoting the non-agriculturalization of household livelihoods, improving ecological compensation, strengthening the evaluation of rocky desertification control and dynamic monitoring, and strengthening research on key ecological function recovery technologies and supporting technologies.

1 Introduction

Karst rocky desertification (RD) is used to characterize the process that transforms a karst area covered by vegetation and soil into a bare rocky landscape almost devoid of soil and vegetation in the fragile karst ecosystems in tropical and subtropical regions (Yuan, 1997; Wang et al., 2004a). In general, water loss and soil erosion take place when surface vegetation is destroyed, leading to land desertification (Barbero-

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finally triggering rocky desertification. In other words, the area has fallen into a vicious cycle of poverty and environmental degradation at different scales (Fig. 3).

3 The challenges rocky desertification control confronted

Rocky desertification control is carried out through the participation of the government, peasants, enterprises, and scientific researchers. It is a continuous process of coordinating various multistakeholders for a common goal. Existing rocky desertification control practices are mainly driven by the government and the role of peasants is not significant. The achievement of rocky desertification control was hindered because various multistakeholders, such as the government, peasants, and enterprises, were overly concerned with their own interests. Furthermore, policies which aimed to achieve a common goal, such as the standards of planting density set by the government, were not effectively implemented because they lacked effective mechanisms to coordinate multistakeholder interests. The construction of governance models was dominated by the government administration, research institutions, and enterprises. Although some good comprehensive benefits were achieved, some governance models were made without considering the current national economic situation. Economic development led to the outflow of the rural labor force and some governance models were overly dependent on external input, which could not be a sustainable development solution since it lacked supporting industries separate from national input (Zhang et al., 2014). Moreover, in the process of formulating rocky desertification governance models, peasants were mainly involved as builders and participants, but were excluded from any independent development of rocky desertification control. Furthermore, some governance models of rocky desertification control did not consider peasants' conditions and needs (Cai and Zhang, 2009), and therefore destroyed any incentive for peasant compliance, especially for those located out of the control demonstration area that were devoid of capital, technology, and other support.

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desertification control technologies. Accordingly, control practices have tended to rely heavily on experience. For instance, restoration vegetation has been mainly composed of afforestation even though dense grasses significantly reduce soil erosion at lower costs and are widely available in a variety of natural environments (Peng et al., 2013); yet, grasses have not been widely promoted. Further research is also needed on the ecological effects of alien plants as well as the control effects of water use and supply technologies.

Most restoration projects have focused on vegetation recovery as a means of assessing the effectiveness of restoration (Young, 2000; Ruiz-Jaén and Aide, 2005), ignoring the recovery capacity of the ecosystem and its resilience to perturbation. At present, the assessment of rocky desertification control and restoration has focused on the economic benefits of governance models and technologies, as well as changes in soil erosion and the physicochemical properties of the soil (Tang et al., 2013; Xie et al., 2015), overlooking an assessment of governance efficiency. Moreover, there has been considerable arbitrariness in establishing evaluation systems and applying evaluation methods, which may consequently have led to the great range of evaluation results in the same area (Zhang et al., 2014). There is also a lack of quantitative data for evaluating ecosystem restoration after control measures have been implemented, such as to what extent the ecosystem should be maintained and managed, what kind of governance policies should be used in follow-up management, and how the health of the restored ecosystem should be monitored. This has caused the management and maintenance of rocky desertification control to fall behind.

In short, rocky desertification control is not only a scientific issue, but also a household livelihood issue (Wang and Li, 2007), which should be addressed with governance methods and technologies, as well as design of policies and public participation. Such an approach is imperative for future rocky desertification control initiatives.

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4 Future improvements of rocky desertification control

4.1 To promote the non-agriculturalization of household livelihoods

The rural labor force outflow caused by China's rapid economic development made an important contribution to the recovery of the ecological environment (Wang et al., 2011). For example, in Guangxi Province in Southwest China, the growth rate of rocky desertification area dramatically decreased during the period of rapid economic development (Liu et al., 2008). There is a clear trend of the rural labor force turning away from agriculture with sustainable industrialization and rapid urbanization (Li, 2008). Currently, there has been a halt in the expansion of cultivated land, along with large-scale de-intensification and abandonment of cultivated land (Ge et al., 2012), which has helped to restore the local ecological environment. The Chinese government has set developing economic zones in the midlands of Guizhou and Yunnan Province in 2014. We should therefore seize the opportunity to further promote the non-agricultural migration of household livelihoods and accelerate the non-agricultural outflow of the rural labor force, while focusing on improving local non-agricultural employment and relocating people for non-agricultural work. It is also the key to break the vicious cycle of poverty and environmental degradation at different scales.

4.2 To improve ecological compensation policies and establish coordination mechanisms of multistakeholders in rocky desertification control

The household livelihood concerns of peasants have changed from maintaining livelihood security to pursuing higher profits. However, with more and more attention being paid to the effects of rocky desertification control on improving local ecosystem services, the private goods function of rocky desertification control is decreasing while its function as a public goods is increasing. Therefore, the biggest beneficiaries of rocky desertification control are the users of the products, not just the peasants. But as the implementers of rocky desertification control, peasants' prime consideration is their

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own utility maximization which is not equal to the overall utility maximization. Therefore, the evaluation standards for utility maximization of rocky desertification control should be made on the basis of all users of the products, not just the peasants. In order to achieve the goal of utility maximization of rocky desertification control, ecological compensation should be provided for peasant participants and appropriately increased according to socio-economic development and inflation. In order to achieve the sustainability of the joint action of various multistakeholders, to clarify the needs of various participants, and to move away from sole government management, a rational coordination mechanism must be established to coordinate the interests of various participants. In order to coordinate the interests of various multistakeholders and achieve the economic, social, and ecological benefits of rocky desertification control, we should attempt to establish a management mechanism based on integrated ecosystem management methods.

4.3 To improve system and methods for evaluating the effectiveness of rocky desertification control and strengthen monitoring and dynamic evaluation

A thorough evaluation system is the foundation of implementing ecological compensation and assessing the efficiency of rocky desertification control. Towards the end of improving the evaluation system, it should be noted that what crucially keeps ecosystems running sustainably are vegetation structure, biodiversity, and ecosystem processes, all of which are essential components of the long-term survival of an ecosystem (Dorren et al., 2004). Furthermore, some recovery indicators based on key ecosystem functions should be established to achieve the recovery of ecosystem functions, such as the degree of biodiversity, the structure and complexity of trophic levels, and particularly litter production and turnover. According to the different degrees of rocky desertification and control objectives in different types of karst geomorphology, we should correspondingly select appropriate reference ecosystems for evaluation and set up a relatively complete evaluation system. In the construction of the evaluation index system, except for directly considering economic benefits, we should also consider the different impacts

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of rocky desertification control on ecological security and ecological service functions, so as to establish reasonable ecological compensation standards and follow-up governance policies. It should be noted that economic values are not natural attributes of the ecosystem but are closely associated with the number of beneficiaries and their socio-economic background. That also implies that, in general, the balance of ecosystem values in a certain region can only be extrapolated to those in similar regions; otherwise, adjustments must be made. In addition, ecosystem restoration is a slow and dynamic process, and there are significant uncertainties for ecosystem development in the recovery process (Bark et al., 2013). Thus, dynamic monitoring of rocky desertification control is conducive to identifying the problems and taking timely corrective measures.

4.4 To strengthen research on key recovery technologies of ecological service function and supporting technologies

The special geological and ecological environment poses a great challenge to the restoration of degraded ecosystems in karst areas (Gillieson et al., 1996). With regard to research on ecological service function recovery technologies in degraded ecosystems in karst areas, we should focus on specific experimental verification techniques of ecological restoration based on different types of geography and climate zones. Since it is difficult to spontaneously recover the structure and functions of a degraded karst ecosystem (such as the storage capacity of epikarst, land productivity, and the natural resilience of vegetation), we should also focus on studying the vital supporting technologies of rocky desertification control, such as storage technology for surface water resources, exploitation and utilization technologies for underground water resources, the selection and breeding of special economic and ecological recovery plants, and optimal configuration technologies and models of adaptive plant communities. Furthermore, karst ecosystems are fragile and very sensitive to changes in the surrounding environment. Climate change has severely affected some aspects of karst ecosystems, such as water resources (Loáiciga et al., 2000), and this is an essential security con-

cern of rocky desertification control. Accordingly, we should strengthen research on the impact of global climate change on karst ecosystems and rocky desertification control.

5 Conclusions

Soil and water conservation in karst ecosystems is one of the fundamental goals of rocky desertification control and is the foundation of local, social, and economic development, especially for peasants. In the process of vigorously implementing rocky desertification control, we must pay close attention to the following two facts: first, the environmental consequences of the same human activities in the karst area of Southwest China are far greater than in similar climate zones because of its special geological and ecological environment; second, the resilience of karst ecosystems is far lower than in similar climate zones, and so it is very difficult for the ecological system to recover from destruction caused by unreasonable human activities. Thus, in order to improve rocky desertification control, we should focus more on eliminating the anthropic factors causing rocky desertification in institutions, policies and economy, and on strengthening preventative measures for ecological degradation. In particular, we must deviate from the existing administrative department framework, which has been divided according to ecosystem elements (e.g. the Forestry Bureau is responsible for forests and the Water Resource Bureau is responsible for water loss and soil erosion), and create policy frameworks that reflect administrative divisions. More importantly, we should formulate regulations and policies according to ecosystem integrity and geographical regions in order to improve this ubiquitous phenomenon, since governance management of rocky desertification control so far has not been that successful.

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Data availability

The data of Tables 1 and 2 are acquired from the Bulletin of Rocky Desertification in China, 2012 and China Statistical Yearbook 2013; the Figs. 1 and 2 are shot by the author in his field investigation.

- 5 *Acknowledgement.* This work was partially supported by the National Natural Science Foundation of China (No.41371045 and No.41261038), the National Social Science Foundation of China (No.13CJY067), and the National Natural Science Foundation of Guizhou province (No. J-2012-2294).

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Table 1. The current state of RD and potential rocky desertification (PRD) in 2012 and the change of RD from 2005 to 2012 in Southwest China.

Province	Guizhou	Yunnan	Guangxi	Hunan	Hubei	Chongqing	Sichuan	Guangdong
RD area /10 ⁴ ha	302.4	284	192.6	143.1	109.1	89.5	73.2	6.3
The proportion of RD area/%	25.2	23.7	16	11.9	9.1	7.5	6.1	0.5
PRD area /10 ⁴ ha	325.6	237.8	229.4	177.1	156.4	87.1	76.9	41.5
The proportion of RD area/%	24.5	17.9	17.2	13.3	11.7	6.5	5.8	3.1
The change of RD area/10 ⁴ ha	-29.23	-4.16	-45.29	-4.81	-3.4	-3.04	-4.31	-1.76
The change ratio of RD area/%	-8.82	-1.44	-19.03	-3.26	-3.26	-3.28	-5.56	-21.57

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Table 2. The current state of socio-economic development and rocky desertification (RD) in the main karst provinces in Southwest China in 2012.

District	RD area /10 ⁴ ha	Per capita cultivated land in rural/ha	Per capita GDP/RMB	Economic growth rate/%	The proportion of primary industry/%	The ratio of dependence upon foreign trade/%
Guizhou	302.4	0.079	19 608	13.6	13	7.62
Yunnan	284	0.107	22 263	13	16	15.9
Guangxi	192.6	0.091	27 952	11.3	16.7	15.76
China	1200.2	0.156	38 354	7.7	10.1	50.57

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Figure 1. Karst rocky desertification in the karst area of Southwest China.

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Figure 2. The peasant cultivated in steep slopes in the karst area of Southwest China. Left: a peasant cultivating on steep slopes in a karst area in Southwest China. Right: rice grows in the center and corn on the surrounding slopes.

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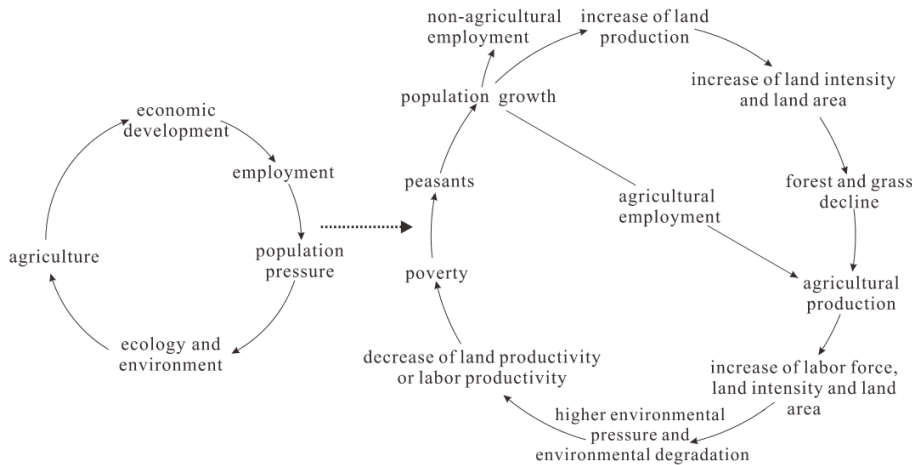


Figure 3. Multi-scale feedback relationship between land use and the ecosystem in the karst areas of Southwest China.

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