SYNOPSIS

Integrated Restoration of Small Watershed in Karst Regions of Southwest China

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Karst is a type of landscape which forms under a specific combination of geological conditions, precipitation, and temperature (Fleury 2009). It contains caves and extensive underground water systems that develop from especially soluble rocks such as limestone, marble, and gypsum (Ford and Williams 2007). Karst regions have always been characterized by environmental problems such as an impoverished ecosystem, soil degradation and erosion, deterioration of water quality and landform destruction (Urich 2002). Thus, a karst region can be considered among the most vulnerable land systems in the world.

The Karst mountainous region of Southwest China is one of the largest karst continuum belts in the world (Huang et al. 2008). Karst geomorphology is mainly concentrated in the Yunnan, Guizhou, and Guangxi provinces. There, the karst system experienced rocky desertification, a process of land degradation whereby an area formerly covered by vegetation and soil is transformed into a rocky landscape almost completely devoid of soil and vegetation. Rocky desertification always leads to progressive impoverishment of local residents, a situation typically exacerbated by pressures from population growth and improper uses of land (Yuan 1997). At one time researchers called it “cancer of the land” (Zhang et al. 2006).

Degradation is most severe in Guizhou province (Zhang et al. 2006; Huang et al. 2008). Biophysical characteristics such as seasonal drought and floods, vegetation degradation, soil erosion, and landslides together with such social-economic issues as poverty and concentrated ethnic minority groups living in remote and less developed areas with low education level, make for a more critical situation than in other

provinces (Xing et al. 2009). The total area of Guizhou province is 176 167 km², of which 92.5 % is hilly and 61.9 % is karst (Xiong 2002). In 2005, 21.3 % of the land was under rocky desertification, while another 31.2 % was in the process of being transformed into rocky desertification land (Fig. 1) (Xiong et al. 2009). There were 23.0 million people, or 66.2 % of the total population, living in the rural areas of Guizhou province in 2010 (Guizhou Bureau of Statistic 2011). On a national level nearly 50.3 % live in rural areas (National Bureau of Statistics 2011). Per capita cultivated land is less than 0.05 ha. In order to make a living in such harsh conditions, local peasants have to cultivate sloping fields, which leads to environmental degradation and further poverty. This vulnerable environmental system co-evolves with a lagging social economy deems this region a hotspot calling for policy attention and research. Interrupting the cycle of poverty is difficult and complex: because of the fragile socio-ecological system, most of the local inhabitants live on subsistence agriculture, it is difficult to extract themselves from poverty trap without external intervention (Reynolds et al. 2007), so assistance from outside such as government, NGOs, and foreign aid is needed.

Following the great floods in 1998, and in consideration of Guizhou being located at the headwater of Zhujiang and Yangtze river, particular focus was given to the rehabilitation of the ecosystem on the part of national decision-makers (Xiong et al. 2009). From then on, local government and researchers have undertaken a lot of measures to combat further degradation of the fragile environment. Some of the measures succeeded as reported by Zhang et al. (2006). The Chinese central government made a commitment in 2005, to input billions of dollars over the 2008–2015 period to restore the ecosystem in 451 counties of Southwest China experiencing severe rocky desertification. There are 78 counties in

Fig. 1 Rocky desertification rate in Guizhou province (based on data from (Guizhou Bureau of Statistic 2010))

Guizhou province, of which 55 were established as pilot projects between 2008 and 2010. A systematic strategy, Integrated Restoration of Small Watershed (IRSW), was devised to apply in these 78 counties between 2011 and 2015. Different from simple measures of ecosystem recovery at site scale (Zhang et al. 2006) and recommendations for antidesertification and researches reported before (Huang et al. 2008), this paper provide a detailed illustration of the systematic approach, Integrated Restoration of Small Watershed (IRSW), for ecosystem restoration in karst areas.

MEASURES OF INTEGRATED RESTORATION OF SMALL WATERSHED

The karst rocky desertification is a synthesis syndrome. In order to rehabilitate degraded land, socio-economic development and ecosystem recovery should be considered simultaneously, with the key issue being the alleviation of pressures of human activity imposed on the land. The IRSW is a new integrated strategy, which connects the development of the local economy with ecosystem recovery and focuses on improving the livelihoods of the residents. The strategy includes seven main aspects that are explained below. Table 1 provides an overview of the restoration strategy. There are seven first-level core measures, each core measure made up of multiple deeper-level measures.

Forest and Grassland Protection and Regeneration

The topsoil of karst land is very shallow. If subject to erosion, it takes thousands of years to regenerate (Wang et al. 1999), so preventing native vegetation from being disturbed is crucial. In remote areas that experienced severe degradation, grazing was prohibited and sign was erected to encourage compliance. Farmlands sloping more than 25° were turned over from farming or raising livestock to forestry or grassland, and fruit trees or timber forest were planted in some of the areas (Fig. 2a). The government paid 586 USD ha⁻¹ per year as compensation for the released land.

Grassland Expansion and Stock Raising

In order to simultaneously increase family income and restore the ecosystem, the government funded the building of sheds for livestock and provided good breeding stock, encouraged peasants to plant fertile grass on the degraded grassland or returned land (Fig. 2b).

Basic Farmland Protection and Water Resources Exploitation

In order to maintain local subsistence farming, farmland productivity should be maximized. Because karst land tends to loose moisture, the hillsides were terraced in order

Table 1 The measures of integrated restoration of small watershed in Guizhou province (Xiong et al. 2009)

First-level measures	Second-level measures	Third-level measures
Forest protection and regeneration	Mountain closure and afforestation	Return land from farming to forestry Plant trees on hillsides
Grassland expansion and stock raising	Grassland expansion Stock raising	Return land from farming to grassland Modify breeding stock Build shed for stock Provide machines to breed stock Build silage pits
Basic farmland protection and water resources exploitation	Turn hillsides into terraced fields and build small water conservancy works Water resources exploitation	Turn hillsides into terraced fields Build road between cultivated lands Build diversion and storm drainage canal Build sediment storage dam Build canal for drawing water from springs Build ponds in hills Build small pools Build de-silting basin
Rural energy development	Build small hydropower station Build bio-gas digester Apply firewood-saving stoves	
Poverty alleviation through relocation and export of labor force	Poverty alleviation through relocation Train labor force for migrating Export of labor forces	
Resources exploitation and regional economy development	Establish characteristic scenic spots Establish fruit plantation and herbal medicine base Establish green agriculture base	
Monitoring system development	Build environmental monitoring stations	

to retain moisture and extend the area of cultivated land (Fig. 2c). Other infrastructure such as the road between fields, the diversion and drainage canal, and the sediment storage dam were built to support and sustain the productivity of cultivated land. Small pools were built in courtyards of residences to collect rainfall and provide drinking water. Ponds were built into hills to collect rainfall for irrigation (Fig. 2d), and the channels for drawing water from springs were built to maintain a water supply. The de-silting basins were built to filter water.

Rural Energy Development

Rural energy development is essential for addressing deforestation, because without other energy options local peasants will continue to cut trees and shrubs for firewood, a practice which leads to vegetation degradation. The rivers in Guizhou province all have a very high vertical drop height, so the potential for a small hydropower station is

obvious. In the courtyards, a biogas digester (which converts manure into fuel) was implemented to provide peasants energy for cooking, with the remains be used as fertilizer. Stoves were also improved to save firewood.

Poverty Alleviation Through Relocation and Export of Labor Forces

In certain regions where pressures of human activity are high, inhabitants should be encouraged to transfer to other places. Young people and adults could receive special relocation assistance, including job training, that would enable them to work in urban settings.

Resources Exploitation and Regional Economy Development

Guizhou province is characterized by a very attractive landscape, fascinating caves, and a rich culture of ethnic

Fig. 2 The integrated restoration of small watershed (IRSW) measures. **a** Forest regeneration, **b** grassland expansion, **c** basic farmland protection, **d** a pond constructed into the hillside. All photographs taken by Ruishan Chen

minority groups, and establishing characteristic scenic spots from these resources could benefit local people. Guizhou province is also characterized by its high-quality fruit, herbal medicine, tobacco, and wine, with greater relative advantages still to be developed. As a result of these pilot projects, local residents adopting new crops such as honeysuckle *Lonicera japonica* and Chinese prickly ash *Zanthoxylum chaffuniani* are earning more than when growing maize (Zhang et al. 2006). These new crops are also less labor-intensive which encourage the peasant to do off-farm works. In one pilot project region, several local families bought machines to take advantage of the available marble, which is abundant in karst areas, as a resource for constructing houses there. Further, diversifying livelihoods has enhanced local resilience.

Setting Up Rocky Desertification Monitoring Systems

The restoration of rocky desertification is a complex process, which cannot be completed in 5 or 10 years. Thus, building monitoring stations, such as underground water and biodiversity observation sites, are essential for collecting data needed to evaluate the effects of rehabilitation and provide useful information for future policy and research.

SOME ISSUES ABOUT RESTORATION STRATEGY AND SUSTAINABLE DEVELOPMENT

Scale-sensitivity governance should be considered. From local to national level, there are different expectations,

level of interest, and scope of resources to cope with restoration. At the national and provincial level, the government determines the development strategy and provides necessary financial and policy support of local projects, thus they should be responsible for evaluating the results of a rehabilitation efforts. At the county and village government level, the focus is on balancing the benefit among different sectors, allocating the fund equally in consideration of distribution both over area and over time. At the local level, the farmers' short-term interests and equal distribution is more important, otherwise they will not cooperate with outside intervention. The peasants also need some training to ensure the new technology will be put into effective use. Researchers and officials should work together with local farmers and respect local knowledge when designing projects.

Owing to the policy of "grain for green," in most mountain countries of Guizhou province families have turned over 50–90 % of their farmland for ecological recovery. After 10 years of policy-related subsidies, the forest still can not benefit the local famers, and farmers said if the government stops subsidizing them, they would reclaim the land from the trees. So payment for ecosystem services by Chinese central government and downstream provincial government is essential to continue maintaining recovery. Guizhou province has plentiful resources, especially tourism and mineral resources, but these resources are hold by national government. Workers are recruited from all over the country and revenues are taken by the government, local residents suffer pollution from industries and gradual sinking of local surfaces caused by mining, but they get little benefit from resources exploitation. Investment in local development is very limited, so if local interests were willing to participate quickly in development, they should also share in the profits. In proceeding with the project, it is essential that participation by local farmers is encouraged to ensure they will not become dependent on outside aid, a scenario wherein when aid stops they return to their former lifestyles. Helping villagers build their regeneration capacity is critical to ensure rural sustainability.

According to Lambin and Meyfroidt (2011), land for agriculture = total land area – (land for nature + settlements). Because of urbanization and ecosystem recovery, conservation together with urbanization compete with agriculture for land. As the availability of land for agriculture is decreasing, food security becomes challenged. So finding the balance between development, environment, and subsistence is essential. Multifunction use of land is promising in Guizhou province because Guizhou is well-known for its wine and tobacco industries, attractive landscapes, and rich ethnic minority traditions.

Because improving local grassland and forest always encourages exotic species to thrive, species growth and sprawl should be carefully monitored to ensure against deleterious results. For example, Chinese prickly ash is said to cause soil degradation, so it is crucial to study the mechanism and find proper solution. "Success stories," or accounts of successfully overcoming issues relating to exotic species growth, would be useful in developing reliable methods of improving grassland and forest.

Because the karst system is a coupled human-environment system, integrated restoration needs a systematic approach that incorporates multi-discipline participation and inter-disciplinary cooperation to overcome challenges. Although many department and research institutions have joined in rocky desertification research, most of them are independent and the data are owned by different institutions. Cooperating by sharing data and research experiences on the Guizhou project can ultimately benefit all researchers and provide important insights, leading to resolution of the challenges involved in restoring the degraded karst mountain ecosystem, and ultimately, alleviation of poverty there.

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