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ORIGINAL ARTICLE

Soil erosion monitoring and its implication in a limestone land suffering from rocky desertification in the Huajiang Canyon, Guizhou, Southwest China

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Abstract Over the past decades, the vast limestone mountain areas in southwestern China have suffered greatly from karst rocky desertification (KRD), which is a unique type of desertification caused by irrational land-use practices and has drawn increasing attention of international academic community. Characterizing soil erosion in this region is the key to understanding the escalating KRD problem and finding solution to it. The authors applied leveling method to study soil erosion process in the Huajiang Karst Canyon area between 1999 and 2003, and tried to relate it to KRD expansion. The monitoring data indicate that soil in the study area was losing at an alarming rate, which is much higher than soil formation rate and has already resulted in severe KRD problem. Soil loss under different land-use conditions varied greatly during the monitoring period. The highest soil erosion rate occurred in bare and newly abandoned cropland, followed by sparse grass land, forest land, and dense grass land. In addition, soil erosion could be significantly different under different micro-topographic conditions. Because soil erosion rate in the studied karst mountain areas is surprisingly high, it is urgent to take quick actions to fight against the ongoing KRD problems in Southwest China before an irreversible situation occurs. However, the traditional way to combat KRD by abandoning current cropland needs to be carefully reconsidered, since a bare newly abandoned cropland may suffer more from rapid soil loss than before.

Keywords Soil erosion · Karst rocky desertification (KRD) · Leveling method · Land use · The Huajiang Canyon · Southwest China

Introduction

Over the past half century, the issues of land degradation and desertification have raised broad concern around the world. According to the definition given by United Nations Environment Programme (UNEP), desertification refers to land degradation resulting from various natural (particularly climatic) and anthropological factors in arid, semi-arid, and sub-humid areas (UNEP 1992). Land degradation under desertification is usually irreversible and featured by the loss of biological productivity and biodiversity and the extension of desert-like conditions (Mainguet 1994). This is the main reason why desertification is also called the cancer of the Earth. Since the 1950s, there has been an increase in publications on desertification. Geographically speaking, the majority of the literature is focused on dry land (Avni et al. 2006; Ghosh 1993; Glantz 1977; Hill et al. 2008;

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Huang and Siegert 2006; Mainguet 1994; Sellers et al. 2008). Desertification problems in humid areas have not yet received proportional attention around the world.

Karst land is an important and unique type of terrain on the Earth's surface, which is usually characterized by extensive outcropping of soluble rocks (overwhelmingly carbonate rocks) and distinguishable morphological and hydrological processes. Overall, karst area covers around 22 million km^2 of the Earth's surface or 15 % of land area, and holds about 1 billion people (Yuan 1997). Southwest China is one of the largest karst areas in the world, and is home to about 100 million people. About 42.6 × 10^4 km^2 land in this area is covered by carbonate rocks, mainly in Guizhou (11 × 10^4 km^2), Guangxi (8.9 × 10^4 km^2), and Yunnan (6.1 × 10^4 km^2) (Wang et al. 2004).

For a long time, China has suffered greatly from a variety of land degradation problems and environmental damages that were mainly caused by irrational human activities. Many researchers paid attention to desertification issues in non-karst regions in northern and northwestern China where climate is mostly arid or semi-arid (Han et al. 2010; Huang et al. 2009; Xu et al. 2010; Zuo et al. 2009). However, desertification in karst areas should behave quite differently and also needs to be addressed appropriately because karst eco-environmental system is fragile and usually featured by low environmental capacity, high sensitivity to external interruption, and poor self-recovery capability (Yang 1990). Karst rocky desertification (KRD) is defined to be a special type of severe land degradation in warm and humid subtropical karst areas that is normally characterized by rapid soil loss, widely exposed bedrocks, decreasing land productivity, and fast expansion of desert-like landscape (Wang et al. 2004). Therefore, KRD is a huge obstacle to achieving regional sustainable development. For the past 20 years, KRD in Southwest China has spread rapidly and become increasingly severe, and thus has drawn broad attention from both Chinese government and academic societies (Huang and Cai 2007; Liu et al. 2008; Xiong et al. 2002; Xiong et al. 2009). In 2001, the State Council of China released its "Outline of the 10th Five-year Plan for National Economical and Social Development", and explicitly declared to combat the escalating KRD problem in southwestern China. On a global scale, KRD issue has not got the attention it deserves over the past few decades, and even has not been on the agenda of the International Desertification Prevention and Control Treaty (Wang et al. 2004). On the other hand, Chinese academic community has carried out a number of studies on KRD for the past decades, trying to understand its geographic distribution, negative impacts, driving forces, and rehabilitation models (Huang and Cai 2006, 2007; Jiang et al. 2009; Li et al. 2009; Liu et al. 2008; Xiong et al. 2002, 2009; Zhang et al. 2010). However, few studies have focused on specific soil loss rate and its relationship to KRD.

Guizhou is one of the provinces with the most severe KRD problems in China. An investigation using remote sensing (RS) in 2004 showed that over 20 % of Guizhou's territory (~3.5 × 10^4 km^2) was ravaged by karst rocky desertification (Wang et al. 2004). Local governments and research institutes are confronted with a huge challenge: how to fight against KRD and achieve sustainable development in the problematic areas? It is generally believed that KRD results directly from soil erosion triggered by vegetation clearance (Liu et al. 2008; Xiong et al. 2002, 2009). However, there is an apparent shortage of knowledge about how fast soil is eroded away in KRD areas and possible relationship between soil erosion and KRD expansion. In this article, the authors, based on their field observations on soil erosion in the Huajiang Canyon area in Southwest Guizhou, are going to (1) examine the rate and surface process of soil erosion in a typical KRD area; (2) unveil the difference in soil erosion under different conditions (i.e., land-use, vegetation cover, micro-topography); (3) compare soil erosion over time in karst (particularly KRD) areas with non-karst areas.

Study area

The study area, located in Southwest Guizhou, covers an area of 47.63 km^2 (Fig. 1). The Beipanjiang River, also called the Huajiang River by local people, is a tributary of the Pearl River in South China, running from northwest to southeast and dividing the study site into two parts. The northeastern part belongs to Guanling County, and the southwestern side is a part of Zhengfeng County. Since the early Tertiary, the Beipanjiang River, influenced by the Neo-tectonic Movement, has intensely incised Guizhou Plateau and formed an amazing canyon across the study site. The so-called Huajiang Canyon, nearly 1,000 m deep, can be morphologically divided into an upper and a lower portion. The upper portion is a wide U-shaped valley (8–10 km in width), and the lower portion is a narrow V-shaped gorge (100–200 m in width). Geologically speaking, the canyon is in accordance with an asymmetric syncline, which dips steeply to the southwest at 50°–70° and gently to northeast at 10°–20°. The majority of the exposed bedrock at the study site is Triassic limestone and/or dolostone, which covers more than 80 % of the land and has developed typical cone karst landforms. A series of Triassic sandstone and shale, exposed only along the bottom of the wide valley, forms a non-karst belt that extends from northwest to southeast.

Subtropical monsoon climate prevails at the study site. Annual precipitation ranges from 1,000 to 1,400 mm and

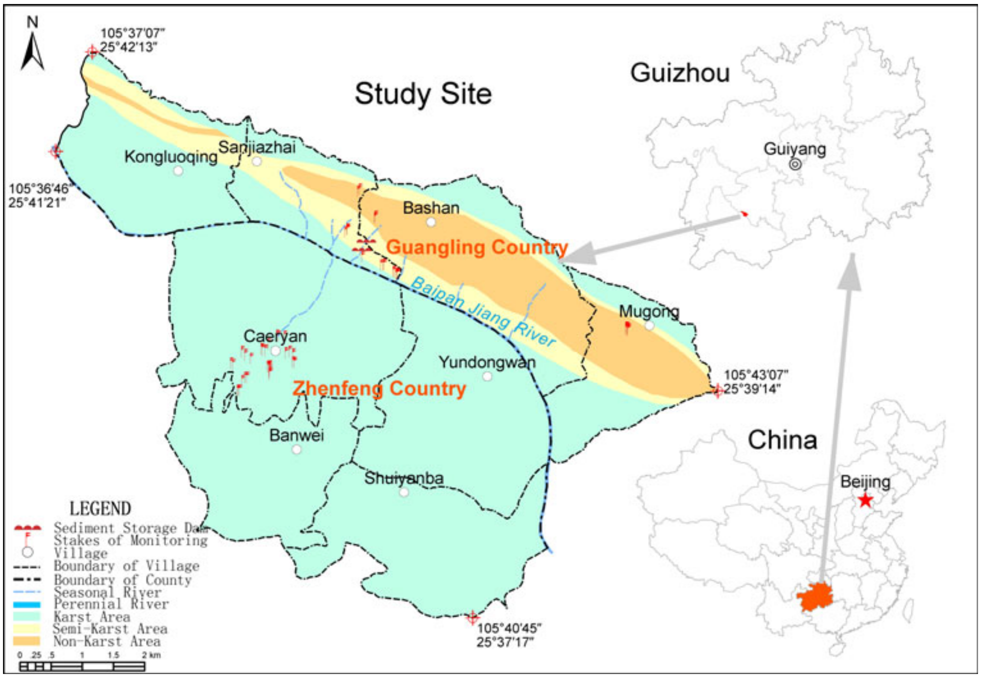


Fig. 1 The location of the study area

mean annual temperature is around 18.5 °C. As a result of long-term irrational land use, karst areas of the Huajiang Canyon have suffered greatly from severe rocky desertification. Natural vegetation has been totally cleared, and persistent soil erosion has already exposed a large area of limestone to air, whereas the remaining soil is thin, poor in organic and scattered in karst fissures, grikes, dolines, depressions, or valleys.

The study site includes 8 villages with a total population of around 6,000 people. Most local people make their living on agriculture and quarry. Natural conditions do not favor agricultural production except in its non-karst region where soil is continual, thick, and fertile enough to grow cash crops as well as grain crops. Overall, cropland is very limited at the study site, and has a total area of about 464 ha. On average, each adult farmer owns only 0.084 ha of farming land, which is about 44 % of the world average level and also less than national average value of China. Limited cropland has given rise to low population carrying capacity. In 2001, the cereal yield per capita at the study site was merely ~220 kg. Apparently, this area was overpopulated, which exerted high population pressure on local environment and land resources. To achieve a subsistence economy under conditions of increasing population, land reclamation through clear-cutting has been an inevitable choice for local people for the past few decades. Under favorable climatic, geological and topographical conditions, vegetation clearance in karst mountain region is usually followed by surprisingly fast soil loss within a very short period of time. As a result, the Huajiang Canyon area has become one of the most severe and typical KRD areas in China (Figs. 2, 3).

Since the late 1990s, a series of major projects, including the 9th, 10th, and ongoing 11th Five-year Key Programs for Science and Technology Development supported by the Ministry of Science and Technology of China, has been implemented in the Huajiang Canyon area, trying to find effective solutions to ecological rehabilitation and strategies for sustainable development in typical KRD regions. To constrain KRD expansion, certain types of cash crops have been introduced to the study area, e.g. *Pericarpium zanthoxyli* in non-karst region of Zhengfeng County, and *Amomum villosum* in karst area of Guanling County. They are shown to be able to conserve soil and increase household income for local farmers. With the implementation of a nationwide Slope Cropland Conversion Project, part of croplands at the study site was required by the Ministry of Forestry of China to be abandoned in 2001, trying to further reduce soil loss and to hold back KRD expansion.

Materials and methods

Soil erosion directly results in the expansion of rocky desertification in karst mountain areas. The direct connection between soil erosion and KRD expansion has been well documented, and a number of methods have been employed to evaluate soil erosion in karst areas, such as Revised Universal Soil Loss Equation (RUSLE), Remote Sensing (RS), and 137Se (Collins et al. 2001; Lv et al.

Fig. 2 The extensively exposed limestone landscape at the study area

Fig. 3 The terraced fields in a karst depression at the study area

2007; Xu et al. 2008). However, it is still not very clear how fast soil is eroded in typical KRD land. In this study, the cost-effective leveling method was adopted to monitor soil loss in the Huajiang Canyon area, which measures vertical shifts of soil surface to quantitatively assess the effect of erosion (Zachar 1982).

Two field trips were arranged to monitor soil loss under different conditions at the study site. The first investigation was focused on the northeastern side of the Huangjiang Canyon. In March 1999, 25 rounded wood stakes, which are about 50 cm in length and 5 cm in diameter, were driven into soils at different locations and the original position of soil surface marked. To minimize human disturbance and obtain reliable data, all stakes were driven into uncultivated land. Among them, 8 were in Duoniudong (a grass-covered talus composed of limestone debris), 4 in Bashan (a non-karst foothill covered by dense grass), and the remaining 13 were in Qinggangpo (a non-karst footslope covered by semi-natural oak forest). Because other natural factors (e.g. variations in humidity, freeze–thaw cycle) may also play a role in vertical changes of soil surface, these negative impacts should be minimized as much as possible and measurements should be made in the same season of the year (Zachar 1982). In April 2000, the vertical changes of soil surface on each stake were measured. Unfortunately, only 16 stakes were found, and 9 stakes in Bashan and Qinggangpo were lost. This might be caused by (1) decay or rottenness under humid conditions, and (2) damage resulting from grazing animals or playing kids.

The second field survey was held in typical KRD areas of Southwest Huajiang Canyon. In April 2002, 50 wood stakes of the same type were driven into soil at different sites with different lithology, land use, and micro-topography. Most stakes were put in the village of Chaeryan, where soil is thick enough to hold stakes (Fig. 4). However, in places where soil is too thin to support stakes, the original soil surface on the exposed bedrock was marked by drawing a red line (Fig. 5). After 1-year erosion, only 25 stakes and 12 red lines were found for making measurements.

Results

The soil erosion monitoring data between 1999 and 2003 are shown in Tables 1, 2 and 3. Clearly, study site experienced an intensive soil loss during the observation period, which was apparently influenced by a number of factors, such as land use, vegetation cover, micro-topography, and lithology.

Soil erosion under different land use and vegetation cover conditions

In the Huajiang Canyon area, land use and vegetation cover are diverse and different from place to place, and three different types can be distinguished: grazed grassland, forest land, and bare newly abandoned cropland. The most severe soil loss apparently occurred in the bare, abandoned cropland and corresponded to the greatest net erosion depth, which was 18 mm during the monitoring period. Soil erosion in the fields covered by semi-natural oak forest or cash crops was relatively higher than that in grassland but much lower than that in the abandoned cropland, with a mean annual net erosion depth ranging from 7 to 5 mm (Figs. 6, 7). Clearly, even though land was not bare but covered by semi-natural or artificial forest, its soil was still susceptible to erosion. In addition, grass cover seemed to be more effective in preventing soil erosion than the other two types of vegetation covers. However, dense grass and sparse grass played quite different roles. The mean net erosion depth per year in the dense grassland was only around 1 mm during the observation period (Figs. 6, 7). In most cases, there was even no soil erosion observed in the fields covered by dense grass. Soil erosion in sparse grassland was ~5–7 times higher than that in dense grassland, with a mean annual net erosion depth of 6 mm.

Soil erosion under different micro-topographic conditions

It is interesting to determine in this study that slope angle did not play an important role in soil erosion under similar land use and/or vegetation cover conditions. Regression analysis shows that the correlation coefficient between the observed net soil erosion depth and the slope angle of the corresponding site is only −0.027 with a significance of 0.846, implying that there is no statistically significant change in net soil erosion depth associated with slope angle at this study site.

However, there was an apparent difference in soil erosion under different micro-topographic conditions in the Huajiang Canyon area, which is consistent with other people's observations around the world (e.g. Pennock and Jong 1987; Quine et al. 1994; De Santisteban et al. 2005). In general, soil erosion on slope surface was much less severe than that on gully bottom. For example, during 1999–2000 monitoring period, the annual net soil erosion depth on slope surface ranged from −3 mm (net deposition) to 19 mm, with a mean value of 6 mm; whereas soil loss rate at a gully bottom in Qinggangpo varied greatly from 12 mm per year at the head to 126 mm per year at the end (Table 1; Fig. 6). During the monitoring period between 2002 and 2003, similar trend was also observed in Chaeryan. Soil erosion rate at grike bottom changed from −3 mm to 119 mm per year, with a mean value of 15.6 mm per year; whereas annual soil loss rate on slope surface was 0–18 mm, with a mean value of only 3 mm (Tables 2, 3; Fig. 7).

Soil erosion under different lithological conditions

Because lithology influences the physical and chemical properties of parent material of soil (Fitzpatrick 1972) to

Fig. 4 Soil erosion recorded by stake-driven method

Fig. 5 The soil loss measured by line-drawing method

a great extent, soil formed on different categories of rocks usually shows different color, structure, granularity, and compactness. As a result, the anti-erodibility of soil may change under different lithological conditions. Two major types of soil can be distinguished in the Huajiang Canyon area: soil developed on sandstone is often sandy, thick, and extensive; whereas soil formed on limestone is usually calcareous, thin, and patchy. Soil erosion also behaved quite differently in karst and non-karst areas under similar conditions. Generally speaking, soil erosion in karst areas was apparently higher than that in non-karst areas. For instance, the mean annual net soil erosion

Table 1 Soil erosion measurements between March 1999 and April 2000

Stake #	Net erosion (mm)	Slope (°)	Underlying rock	Vegetation cover	Micro-topography
1	2	31	Limestone	Dense grass	Slope surface
2	−3	31	Limestone	Sparse grass	Slope surface
3	0	31	Limestone	Sparse grass	Slope surface
4	7	31	Limestone	Sparse grass	Slope surface
5	7	31	Limestone	Sparse grass	Slope surface
6	5	31	Limestone	Sparse grass	Slope surface
7	19	31	Limestone	Sparse grass	Slope surface
8	14	31	Limestone	Sparse grass	Slope surface
9	3	31	Sandstone	Dense grass	Slope surface
10	−1	24	Sandstone	Dense grass	Slope surface
11	7	24	Sandstone	Sparse grass	Slope surface
12	7	19	Sandstone	Forest (oak)	Slope surface
13	9	19	Sandstone	Forest (oak)	Slope surface
14	4	19	Sandstone	Forest (oak)	Slope surface
15	12	17	Sandstone	Bare	Gully bottom
16	126	22	Sandstone	Bare	Gully bottom

(1) Stakes # 1–8 were from Duoniudong, 9–11 from Bashan, 12–16 from Qinggangpo. (2) Stakes # 15 and 16 were placed at the head and end of a gully respectively. (3) Negative sign in the "Net erosion" column indicates a net deposit

Table 2 Soil erosion recorded on stakes between April 2002 and April 2003

Stake #	Net erosion (mm)	Slope (°)	Underlying rock	Land use	Veg. cover	Micro-topography
1	1	21	Limestone	AC	Bare	Grike bottom
2	5	21	Limestone	AC	Sparse grass	Grike bottom
3	5	5	Limestone	AC	Bare	Grike bottom
4	3	5	Limestone	AC	Sparse grass	Grike bottom
5	3	30	Limestone	AC	Bare	Grike bottom
6	119	21	Limestone	AC	Bare	Grike bottom
7	0	10	Limestone	AC	Sparse grass	Grike bottom
8	7	32	Limestone	AC	Sparse grass	Terraced cropland
9	2	10	Limestone	AC	Sparse grass	Grike bottom
10	−3	10	Limestone	AC	Bare	Grike bottom
11	2	16	Limestone	UG	Dense grass	Grike bottom
12	4	15	Limestone	AC	Sparse grass	Terraced cropland
13	1	18	Limestone	UG	Dense grass	Slope surface
14	0	18	Limestone	UG	Dense grass	Slope surface
15	0	20	Limestone	UG	Dense grass	Slope surface
16	0	15	Limestone	UG	Dense grass	Slope surface
17	0	25	Limestone	UG	Dense grass	Slope surface
18	0	25	Limestone	UG	Sparse grass	Slope surface
19	0	41	Shale	UG	Dense grass	Slope surface
20	1	41	Shale	UG	Dense grass	Slope surface
21	18	30	Sandstone	UG	Sparse grass	Slope surface
22	4	30	Sandstone	UG	Dense grass	Slope surface
23	0	27	Sandstone	CCP	Cash crop	Slope surface
24	7	27	Sandstone	CCP	Cash crop	Slope surface
25	9	24	Sandstone	CCP	Cash crop	Slope surface

AC abandoned cropland, *UG* unused grassland, *CCP* cash crop planning

depth in karst areas ranged from 6 mm in Duoniudong (1999–2000) to 11 mm in Chaeryan, whereas the mean yearly soil loss in non-karst areas was just about 5–6 mm (Figs. 6, 7).

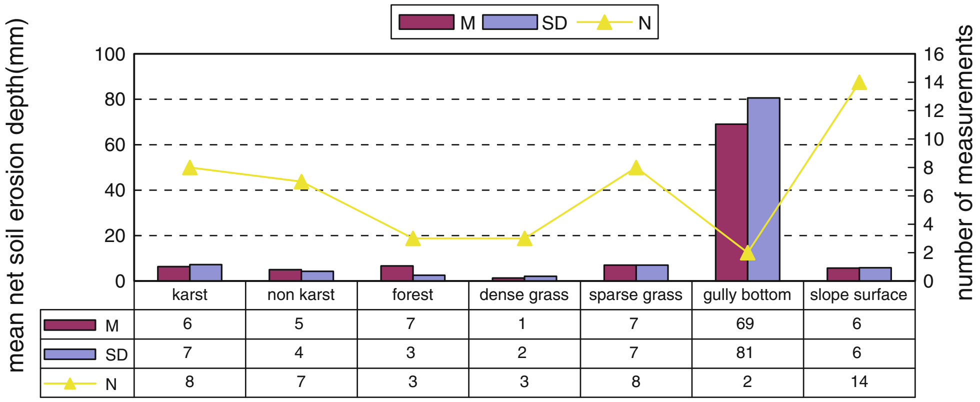
Discussion

It is generally believed that stopping cultivation may be a good way to reduce soil erosion. However, a newly

Table 3 Soil erosion recorded by drawing lines in abandoned cropland between April 2002 and April 2003

Line #	Net erosion (mm)	Slope (°)	Underlying rock	Land use	Veg. cover	Micro-topography
1	2	15	Limestone	AC	Bare	Grike bottom
2	−3	15	Limestone	AC	Bare	Grike bottom
3	5	15	Limestone	AC	Bare	Grike bottom
4	2	15	Limestone	AC	Bare	Terraced cropland
5	2	10	Limestone	AC	Bare	Terraced cropland
6	8	20	Limestone	UL	Bare	Grike bottom
7	38	21	Limestone	UL	Bare	Grike bottom
8	22	32	Limestone	AC	Bare	Terraced cropland
9	41	15	Limestone	AC	Bare	Grike bottom
10	37	10	Limestone	AC	Bare	Grike bottom
11	15	18	Limestone	AC	Bare	Grike bottom
12	12	15	Limestone	AC	Sparse grass	Terraced cropland

UL unused land



	karst	non karst	forest	dense grass	sparse grass	gully bottom	slope surface
M	6	5	7	1	7	69	6
SD	7	4	3	2	7	81	6
N	8	7	3	3	8	2	14

Fig. 6 The mean net soil erosion depth under different conditions from March 1999 to April 2000 (here, *N* number of measurements, *M* mean net soil erosion depth, *SD* standard deviation)

	karst	non karst	bare	cash crops	dense grass	sparse grass	grike bottom	slope surface
M	11	6	18	5	1	6	16	3
SD	24	7	16	5	1	8	29	5
N	30	7	14	3	8	9	18	13

Fig. 7 The mean net soil erosion depth under different conditions from April 2002 to April 2003 (here, *N* number of measurements, *M* mean net soil erosion depth, *SD* standard deviation)

abandoned cropland may even suffer more from erosion than before. Cerdá's (1997) conducted a thorough comparison study on soil erosion among a bare cultivated field, a 3-year-abandoned field, a 10-year-abandoned field, and two soil units covered with semi-native and native vegetation in the southeastern Spain. He found that runoff

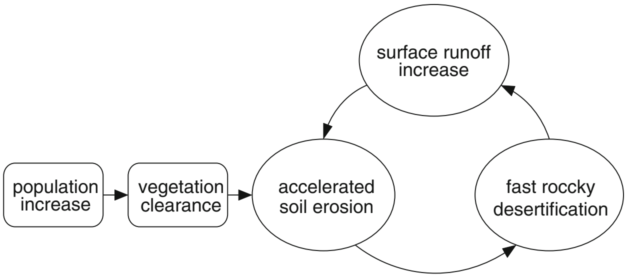


Fig. 8 The feedback loop between soil erosion and KRD expansion in karst mountain areas

discharge and erosion rate increased immediately after land abandonment but decreased later owing to gradual increase in vegetation cover. For fields abandoned for 10 years and covered by native or semi-native vegetation, the site conditions were very stable, producing almost no runoff and erosion. Similar tendencies were also observed in Mediterranean region: runoff and erosion rates were the lowest in semi-natural fields, and the maintenance of semi-natural vegetation may help to prevent runoff generation and erosion (Díaz et al. 1999). In the Huajiang Canyon area, the monitoring data show that the newly abandoned cultivated land was undergoing severe soil erosion and grass cover (particularly dense grass) is much more helpful than forest in preventing soil erosion. Therefore, before these abandoned croplands are re-covered by grass in a natural way, it is urgent to take measures to hold back soil erosion, especially in grikes where soil is being lost at an alarmingly high rate. Otherwise, the fast-going erosion will deplete the remaining soil in a very short period of time and may result in rapid KRD expansion.

For the past few decades, the remote mountain regions of China have been under great pressure to create more arable land due to rapid population growth. With more mouths to feed, local farmers used to clear vegetation cover to obtain more croplands at the study site. As a result, the area often experienced severe soil erosion and more underlying carbonate rocks were exposed to the surface. With time passing by, local soil was getting thinner and thinner, and soil water holding capability would decline, which would in turn decrease infiltration and increase surface runoff. Eventually, this would lead to more erosion on both remaining soil and the exposed carbonate rocks. Unexpectedly, KRD was never a gradual and slow process but occurred in a sudden and fast way. Therefore, once vegetation cover is cleared in karst mountain areas, a negative feedback loop between soil erosion and KRD expansion will be triggered (Fig. 8). This also explains to a great extent why the measured soil erosion rate is apparently higher in the karst areas of the Huajiang Canyon.

According to field observation and interviews with local people, a lot of soil has been lost in a very short period of time over the past few decades at the study site. This can be further verified by the evidences kept in a number of karst grikes near Chaeryan, where soil used to be relatively thick

Fig. 9 The fast erosion and remaining soil in a karst grike near Chaeryan (*dashed line* represents previous soil surface)

and arable. The upper portion of the exposed limestone is usually rough and relatively dark in color due to a long-term sub-aerial corrosion, whereas the lower portion is newly exposed to atmosphere by fast soil erosion and is normally characterized by smooth and relatively light-colored surface owing to subsoil erosion. The persistent and rapid soil erosion has soon led to an extensive exposure of underlying limestones and also made the differences visible between sub-aerial corrosion and subsoil corrosion (Fig. 9).

It is well agreed that soil forms at a very slow rate in karst areas. Yuan and Cai (1988) estimated that the formation of 1-cm-thick soil in limestone areas would usually take thousands of years. Once soil is entirely eroded away, local ecosystem may collapse. It is thus absolutely necessary to take countermeasures as early as possible to hold back the fast and extensive expansion of KRD land before situation is getting worse and becomes irreversible.

Conclusions

In this paper, the results of field investigation were reported on soil erosion under different conditions in the Huajiang Karst Canyon area in Southwest China over a 2-year period from 1999 to 2000 and from 2002 to 2003, and the possible connection between soil erosion and expansion of karst rocky desertification (KRD) was also discussed. The monitoring results indicate that the study site was losing soil at an alarming rate, which is far greater than soil formation rate and is thus causing rapid expansion of KRD. Soil erosion under different conditions varied greatly during the monitoring periods. From 1999 to 2000, the recorded mean net soil erosion depth was 7 mm in forest land, 1 mm in dense grass land, and 7 mm in sparse grass land. For observation period between 2002 and 2003, local soil losing rate was recorded as 18 mm year^{-1} in bare and abandoned cropland, 5 mm year^{-1} in cash cropland, 1 mm year^{-1} in dense grass land, and 6 mm year^{-1} in sparse grass land. Clearly, soil erosion rate differs under different land use and vegetation cover conditions at the study site, with the highest rate observed in bare and newly abandoned cropland, followed by sparse grass land, forest land, and dense grass land. Therefore, grass cover, particularly dense grass coverage, is the most effective vegetation cover category that can significantly reduce soil erosion. Due to the low cost of grass and its wide availability in a variety of natural environments, planting native grasses instead of trees may be a better way to fight against KRD problem.

It was determined that different micro-topographic conditions usually lead to obviously different soil erosion. The 2-year monitoring data at the study site showed that soil erosion rate at the bottom of a gully or grike is 5–12 times faster than that on slope surface. It is also observed that soil erosion rate in karst area is apparently higher than that in non-karst area. In stony karst areas, as time goes on, more carbonate bedrocks will be exposed to air by soil erosion. As a result, the water holding capability of soil will decline, and same amount and intensity of precipitation will produce more surface runoff due to less infiltration, and therefore would result in a more rapid soil erosion than previous period in karst areas. It implies that soil erosion might accelerate once rocky desertification starts, which will lead to fast disappearance of soil in a short time. In addition, once vegetation cover in karst area is cleared, a negative feedback loop between soil erosion and KRD expansion will be triggered. This will eventually lead to rapid expansion of KRD. It is thus very urgent to take effective measures to fight against the ongoing KRD issue in Southwest China as early as possible before it becomes irreversible. However, the traditional way to combat KRD (e.g. abandoning cropland in steep slope areas) needs to be carefully reconsidered. This is because a bare, newly abandoned cropland may suffer more from rapid soil loss than before. It is very necessary to take cost-effective engineering measures to hold back or alleviate rapid soil loss before the abandoned cropland is re-protected by vegetation through natural recovery.

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