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Land Use Changes and Gully Development in the Upper Yangtze River Basin, SW-China

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Abstract: More than 80% of the gullies in Southwest China are not active today due to a cover with young vegetation. The objective of this study is to investigate the development of these gully systems and their relation to land use changes over the last 2000 years. The first investigations were carried out at the slopes bordering of the Anning Warm-Dry Valley of southern Sichuan in the territory of Xichang. Two gully systems were investigated in details. The size (length, average depth and width) and the volume of the gully system were measured in the field and calculated. The size of the surface catchment of the gully system was measured in the field, too. Air photos were analyzed, senior experts and farmers were interviewed for a detailed reconstruction of land use history. After several centuries of sustainable landscape development namely the intensive agricultural land use during the second half of the 20th century caused excessive floods and gullying in wide parts of southern Sichuan. Valley bottoms were flooded, rivers changed their position, many villages ceased there and lakes were filled with sediments. Gullying rates that could be reconstructed are unexpectedly high and strongly demand sudden successful measures of soil and water conservation.

Key words: gully erosion; land use change; the Upper Yangtze River Basin

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1 Introduction

Gully erosion is a major environmental problem in the mountainous regions of Southwest China [1]. More than 80% of the gullies are not active today. Young vegetation covers most gully walls and gully bottoms [2]. When did the gully systems develop? Will future heavy rainfall and concentrated overland flow reactivate them? How relevant are specific land use systems and landscape structures for the development of gullies?

To answer these questions a joint sino-german research project started to investigate the landscape development since the rise of agriculture in some characteristic small catchments of the upper Yangtze River Basin. The first investigations were carried out at the slopes bordering of the Anning Warm-Dry Valley of southern Sichuan in the territory of Xichang. The average annual rainfall in the city of Xichang amounts to 1000 mm. Most rain is

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Biography(作者简介): Prof. Dr Hans-Rudolf Bork (1945—), Chair, Director of Ecology-center, Christian-Albrechts-University Kiel, Germany. Generalist in Ecosystem Research, Landscape Ecology, Landscape Development, Sustainable Development of Rural Areas. Hans—Rudolf Bork (1945—), 博士, 德国科尔大学生态中心主任, 教授。主要从事土壤科学、地貌学与景观生态方面的研究。撰写研究专著9部, 发表学术论文80余篇。

falling during late June, July and early August. An average annual temperature of 17 ℃ was recorded at Xichang. Temperatures are decreasing and rainfall is increasing from Anning Warm-Dry Valley to the neighboring mountains.

2 Methods

Soils and sediments were investigated, air photos were analyzed, senior experts and farmers were interviewed for a detailed reconstruction of land use history. The spatial and temporal relations of a specific gully system to soils and sediments in their surroundings were identified. Thus the important question was answered, if the soils and sediments nearby were older or younger than the gullies. Then an exact stratigraphy (logical sequence of changes in space and time) of land use, soil formation, soil erosion and sedimentation was developed. The size (length, average depth and width) and the volume of the gully system were measured in the field and calculated. The size of the surface catchment of the gully system was measured in the field, too.

In a complex interdisciplinary approach the results of the soil profile and sediment analysis, of the air photo interpretation, of the inquiries and the gully investigations were compared, integrated and interpreted. Finally the gully erosion rates were calculated for specific land use systems and land use periods.

First results from two small catchments nearby Xichang City are presented in this paper.

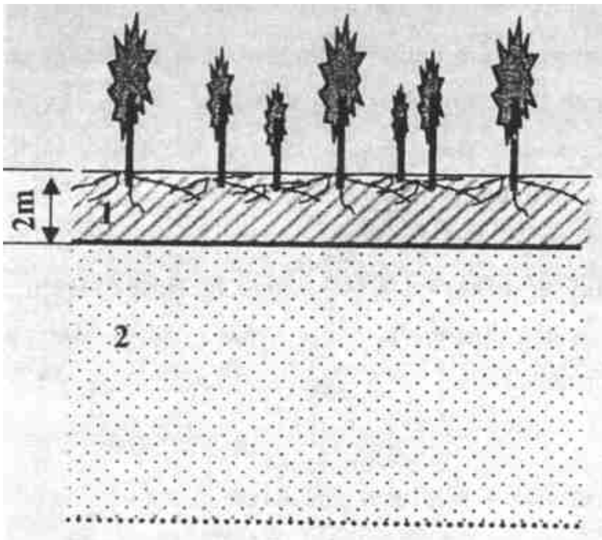
3 The Development of the Xixi Gully System

At the east exposed slope of the Long Mountain Ridge in the Xixi Rgion severe gullying has occurred in the past. Extended gully systems cover wide parts of the slopes. Near the small village of Yuanjiawan on the slope mentioned a gully system was investigated in detail. The area is located at 27°43′46″north and 102°13′20″ east in heights from 1549 m to 1615 m above sea level.

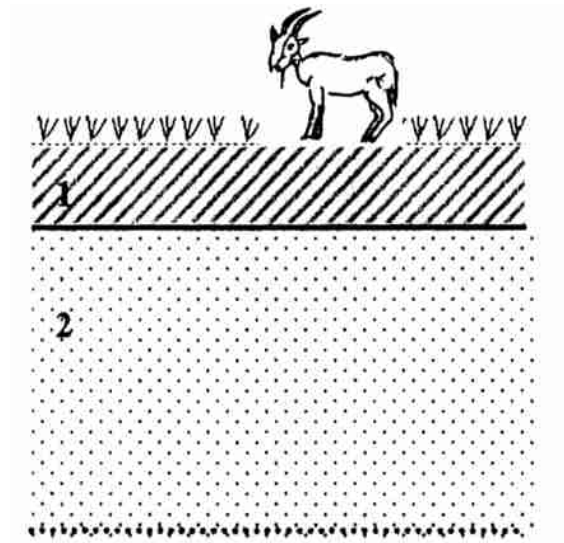
Dense natural woodland was covering the slopes of the Long Mountain Ridge near Yuanjiawan and thus preventing soil erosion before the year 1958. Intensively weathered deep red soils formed over several thousand years under the dense woodland (Fig. 1). Following a national initiative, all trees were cut in 1958. A national decision in late 1958 to plant a forest in the area failed. Pine tree seeds distributed by airplanes (air seeding) were removed by farmers and fed to their animals. Then, for seven years the slopes were grazed. In the year 1965 the grazed grassland of the Long Mountain Ridge was replaced by agricultural terraces. Most terraces were fixed by earth walls only. The surfaces of the agricultural terraces were inclining smoothly in the direction of the steep slope.

No gullying has occured during the past periods of natural woodland (before 1958) and grazing (1958 ~ 1965), the soil surface has been stabilized by vegetation over thousands of years. After 1965 rainfall caused splash erosion and surface compaction on the non-vegetated surfaces, namely on several small paths and farm roads. Additionally animals and people using the paths and roads compacted the soil surface and reduced the infiltration capacity dramatically. During heavy summer rainfall the infiltration capacity of these areas was exceeded and overland flow was concentrating on paths and roads, flowing then along dells downslope. During one excessive summer rain, large amounts of concentrated overland flow cut into the red soil at the steep downslope area of the catchment. The development of the gully system began. It is unknown, how many heavy rainfall events increased the gully system in the following years.

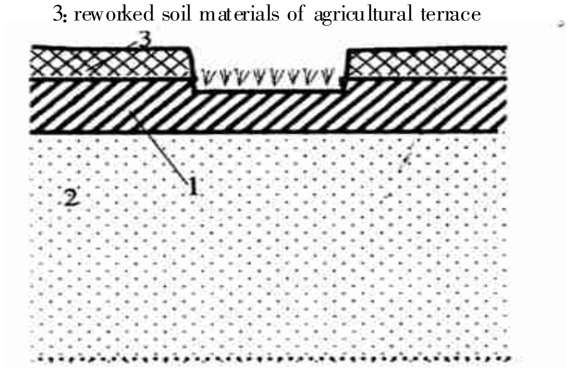
Phase 1 Soil formation in natural woodland, before 1958
1: A— and B— horizon of red soil
2: weathered shales



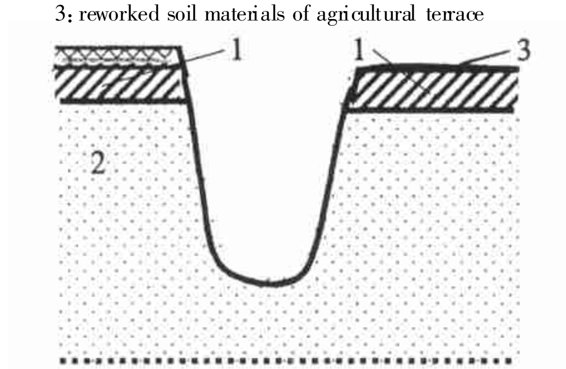
Phase 2 Deforestation and grazing (1958～1965)
1: A— and B— horizon of red soil
2: weathered shales



Phase 3 Establishment of agricultural terraces (1965)
1: A— and B— horizon of red soil
2: weathered shales
3: reworked soil materials of agricultural terrace



Phase 4 End of gully development period (1985)
1: A— and B— horizon of red soil
2: weathered shales
3: reworked soil materials of agricultural terrace



Phase 5 After a forestation (2000)
1: A— and B— horizon of red soil
2: weathered shales
3: reworked soil materials of agricultural terrace
4: sediment deposited at gully bottom before total cover with trees
5: pine tree

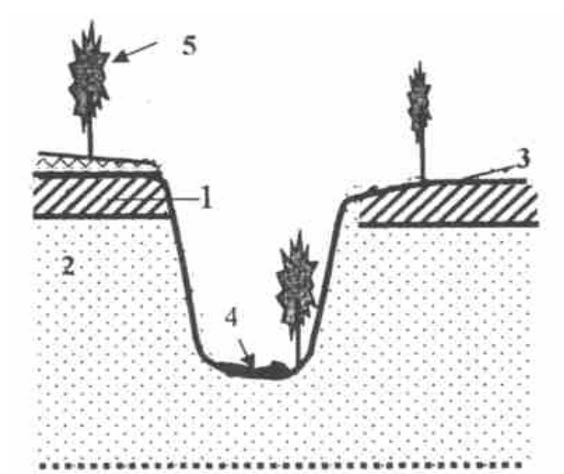


Figure 1 Model of the development of the Xixi-gully system

Today the main gully system has a total length of more than 400 m. A maximum gully depth of 5 m was recorded by the authors. In average the gullies have a depth of 3.7 m and a width of 4.3 m (Table 1). An average cross section of 16 square meters multiplied with the total length of the gully system results in a volume of 6400 cubic meters of soil removed by gullying. Small and short tributary gullies eroded an additional amount of 200 cubic meters of soil.

In the year 1985 a pine forest was established successfully by air seeding. Agriculture had to stop. Soon the slopes became green and were protected against severe gully erosion. Until today the catchment is covered with pine trees and grazed. Soil erosion is reduced to minor rill erosion at a few paths in the north of the catchment since the late 1980s. At most sites the sharp gully edges and the steep gully heads that developed approximately from 1965 until 1985 were protected by the pine forest until today (December 2000). Only at a few spots soil slided down the steep gully walls during the past years, filling the gully bottom partly.

Table 1 Size of the Gully System of the Xixi Research Area

maximum depth	5 m
average depth	3.7 m
average width	4.3 m
average cross section	16 square m
length of the major gully system	405 m
volume of the major gully system	6400 cubic m
volume of small tributaries	200 cubic m
volume of the total gully system	6600 cubic m
average bulk density of soil eroded	1.5 g per cubic cm
tons of soil removed by gullying	9900 tons
approx. maximal duration of gullying	1965 ~ 1985
size of the catchment of the gully system	1.4 hectares
average gullying rate for 20-year period	250 cubic m per hectare and year or 375 tons per hectare and year

The size of the catchment of the gully system amounts to 1.4 hectares. Assuming a maximum duration of gullying from 1965 until 1985 the volume of 6600 cubic meters of soil was removed in 20 years only. Assuming constant gully erosion over two decades, an average annual gullying rate was 250 cubic meters per hectare. In reality only a few rainstorms will have eroded the gully system in some monsoon summers between 1965 and 1985.

The enormous high rate of gully erosion reconstructed can be explained by

— highly erodible soils,

— low infiltration capacities,

— steep slopes,

— surfaces of agricultural terraces inclined in the direction of the slope,

— weak walls of the agricultural terraces,

— paths and dells where overland flow was allowed to concentrate, and

— at least locally a low vegetation cover density during the monsoon months.

The land use changes, the gully erosion history and the erosion rates of the small catchment investigated are characteristic for the slopes bordering the extended Anning Dry Valley.

4 Landscape Development in the Daqingliang Research Area

A regional war ended the long period of slope stability and of soil development suddenly in the nearly totally wooded area of Daqingliang. In 1887 the-at that time-minority of Han were again attacked in the Anning Dry Valley by members of the Yi which lived as hunters, gatherers and primitive farmers in the Daqingliang area and other neighboring mountains. Thus, in 1887 the Han burned the woodland of the mountains of Daqingliang. The charcoals of this fire can still be found today in the sediments of the research area of Daqingliang, which is situated at 27°42′25″ morth and 102°21′50″ east in a height of approximately 2550 meters above sea level.

After the forest fires of the year 1887 the land was grazed only extensively (Table 2). Around 1955 sheep-grazing was intensified-a process still being active. An attempt to establish a pine forest by air-seeding in 1958 was not successful due to intensive grazing and due to the cold mountain climate which avoids growing pine trees. Since 1963 cattle is held in growing numbers, too.

Table 2 Land Use Changes in the Daqingliang Research Area

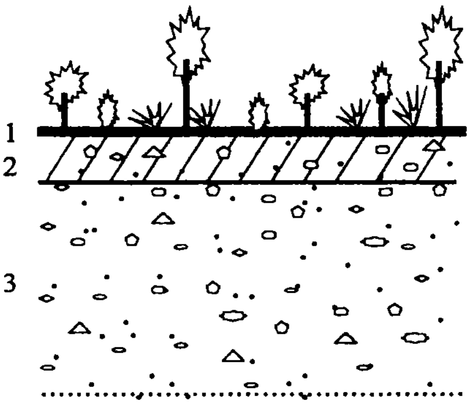
~1887	woodland (rare cutting of trees, at a few sites primitive agriculture of Yi)
1887	burning of woodland during regional war
1887~1955	wasted land, extensively grazed
1958	air-seeding of pine trees (not successful)
1955~1963	medium intensive grazing (sheep) on midslope and upslope areas
1963~2000	intensive grazing (sheep and cattle) on midslope and upslope areas
1955~2000	agriculture on downslope areas (wheat, potatoes, grass)

The dramatic reduction of biomass in the area (grassland and arable land instead of forest) decreased transpiration and infiltration rates and made overland flow possible during rainstorms[3~5]. High soil moisture contents during the monsson months lowered the stability of the dark brown soils and underying sediments. Landslides were unknown before 1887 and rare before 1955. Since the mid 20th century they occured in increasing numbers. Earthquakes may have triggrered the land slides, too. Additionally heavy rainfall with concentrated overland flow and severe floods hit the area, namely in July 1978, June 1985, September 1989 and July 1998. We expect that these rainstorms caused the development of large gullies with depths up to 18 m in the Daqingliang Research Area (Fig 2). Large blocks with diameters of 1 m and more were transported. The senior experts Liangru Li. Director of the Agricultural Bureau of Xichang Territory, and Xinzhi Yang, Director of the animal husbandry bureau of the xichang territory, and local farmers, too, report that the gullies developed approximately during the last two decades only. Since the blocks in the gullies were not covered with lichen or other vegetation a transport during the last few years (during the 1998 rainstorm ?) is very probable.

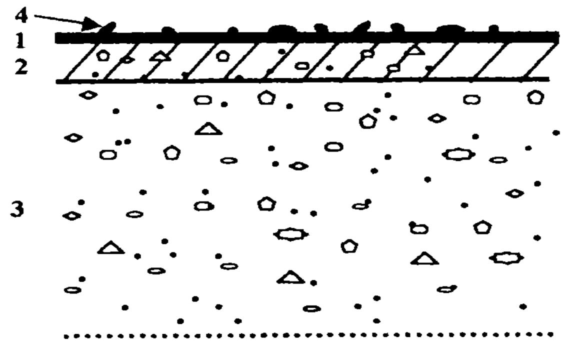
5 Conclusions

After several centuries of sustainable landscape

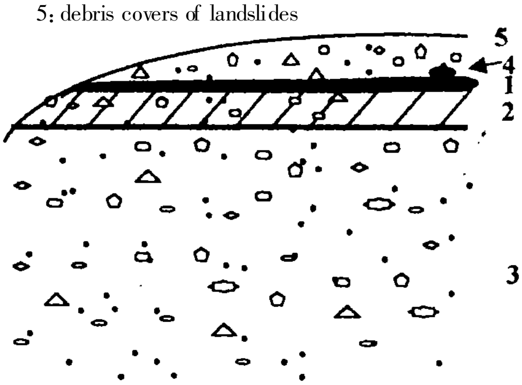
Phase 1 **Soil formation in natural woodland before** 1987
1: humic horizon
2: B— horizon developed in debris cover
3: several debris covers (probably Pleistocene)



Phase 2 **Man-made fire destroys the natural woodland in** 1887
1: humic horizon
2: B— horizon developed in debris cover
3: several debris covers (probably Pleistocene)
4: chacoal



Phase 3 **Landsides in grazed land** (20th **century**)
1: humic horizon
2: B— horizon developed in debris cover
3: several debris covers (probably Pleistocene)
4: chacoal
5: debris covers of landslides



Phase 4 **Gullying in intensive grazed land** (**late** 20th **century**)
1: humic horizon 2: B— horizon developed in debris cover
3: several debris covers (probably Pleistocene)
4: chacoal 5: debris covers of landslides
6: block which slided into the gully
7: coarse gully bottom sediment

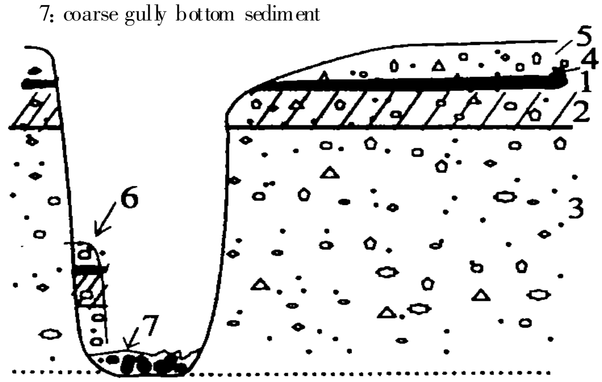


Figure 2 **Langscape development in the Daqingliang research area**

development namely the intensive agricultural land use during the second half of the 20th century caused excessive floods and gullying in wide parts of southern Sichuan. Valley bottoms were flooded, rivers changed their position, many villages ceased there and lakes were filled with sediments. Gullying rates that could be reconstructed are unexpectedly high and strongly demand sudden successful measures of soil and water conservation.

Future research should focus on the event-based dating of the 20th century gully erosion, hillslope erosion and landslide events as well as on the exact quantification of erosion. More sites under investigation will then prove the regional relevance of the examples documented in this paper.

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Reference:

[1] Li Y., Poesen J., and Zhang J. H., 2000. Gully erosion: an urgent problem needing consideration in China. Proceeding of International Symposium on Gully Erosion under Global Change, Leuven, Belgium, 17～19 April, 2000.

[2] Zhang J. H., Li Y., Lindstrom M. J., and Yang Z., 2000. Soil water properties in a recently established forest as affected by grazing in a semiarid valley, Soil Use and Management 16, 234～235.

[3] Zhang J. H., Li Y., Yang Z., 2001. Relationship of vegetation growth to soil infiltration in the dry-hot valley of Yuanmou, Yunnan Province, J. Mountain Science 18. (in press)

[4] Li Y., Zhang J. H., Lobb D. A., and Zhang J. G., 2000. Tillage translocation and tillage erosion processes and their Implication for agro-ecosystems. J. Mountain Science 18, 514～519.

[5] Li Y., 1995. Plant Roots and Soil Anti-scouribility, Science Press, Beijing. 133PP.

长江上游土地利用变化与冲沟发生和演变

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摘　要: 冲沟侵蚀是中国西部山区一个重要的环境问题。小流域研究表明, 黄河和长江中的泥沙主要是冲沟侵蚀引起的。目前, 长江上游 80% 的冲沟因被幼林草植被覆盖而处于非活跃期。到底这些冲沟系统是什么时候形成的? 未来的暴雨和径流是否会激活这些冲沟系统? 土地利用与景观结构对冲沟系统的发生、演变有何关系? 基于这些问题, 近几年来在中科院山地环境学"百人计划"和"国外引进杰出人才"项目及德国洪堡基金的资助下, 中德科学工作者进行了合作研究。本文介绍了长江上游地区土地利用变化与冲沟发生、演变的部分研究成果。我们在西昌安宁河干暖河谷选择了两个冲沟系统: 一个位于西溪乡长山岭, 一个位于大青梁子。为了定量评价土地利用对冲沟发育的影响, 我们对研究小流域的航片、土壤剖面、泥沙堆积与土地利用历史等进行了详尽的综合对比分析。同时, 对两个冲沟系统的大小和土壤流失的体积进行了详细的野外调查、测定和计算。据此, 获得了研究流域的冲沟侵蚀速率。研究结果表明, 长江上游数百年的持续景观演变, 尤其是 20 世纪中期人为强烈的不合理农业垦殖和利用土地, 造成了四川西南部大量冲沟系统的形成和发展, 研究流域的冲沟侵蚀速率高达 375 $t/hm^2 \cdot a^{-1}$。采取成功的水土保持措施以控制冲沟侵蚀, 对中国西南山地退化环境的生态修复具有重大实践意义。

关键词: 冲沟侵蚀; 土地利用变化; 长江上游
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