

The comparison of the effects of two approaches to control gully erosion in the Black Soil Region of China

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Abstract: Gully erosion is an important form of soil erosion, however, little was done on the effect of gully erosion controlling approaches. A program for controlling gully erosion was carried out in Heshan Farm in black soil region of northeast China from 1994 to 1996 include two approaches: “Soil fill” and “Vegetation cover”. From the investigation at 2009, Soil fill approach can protect the original place of gully erosion well, but this approach ignores the whole impact at the catchment scale, and may cause to new gully appear. “Vegetation cover” approach is better to control gully erosion than “Soil fill” approach, but has little effect on controlling the headcut retreat.

Keywords: gully control, soil fill, vegetation cover

Introduction

As more and more researchers have begun to pay more attention to gully erosion, a lot of approaches were developed to control gully. We can simply divide these approaches into three kinds. First one is to try to stabilize the gully. One typical example is the vegetation cover method. Trees and grasses are planted on gully’s bottom and bank, which can provide protection against flow scour (Deletic 2001, Rey 2003). Second one is to control the runoff flow from upstream of the gully, for example, establishing the grass hedges at concentrate flow area (Poesen et al. 2003), and building the spillways and aprons at the upstream of gully to decrease the amount and energy of the runoff (Valentin et al. 2005, Meng 2009). Third one is that some soil conservation works are built inside the gully to restore the hydraulic balance of the gully, for example, different kinds of check dams inside the gully to trap the sediment yield, which can decrease the slope gradient of the stream (Morgan 1986, Husdon 1995, Bi et al. 2002, Nyssen et al. 2004).

Methods

Study area

Our study area (48°59′03.37″N to 49°02′35.07″N, 125°15′45.71″E to 125°20′46.79″E) is located in the Black Soil Region, in China’s Heilongjiang Province. The region’s climate is continental-semihumid, with mean temperatures in January and July of –21 and 21°C, respectively. The annual precipitation is about 535 mm. The slope gradient of the study area is very gentle, and its main range is between 2% and 14%, but the length of the slope is pretty long, and its range is between 500 m to 4,000 m.

The topsoil association is classified as a Udic Argiboroll in the USDA Soil Taxonomy or a Luvic Phaeozem in the FAO/Unesco system, silt clay loam and clay loam are the main textural classes of the black soil, and the organic matter content ranges from 3% to 5%. Soil dry bulk density ranges from 1.0 to 1.5 g cm⁻³, and averages about 1.27 g cm⁻³. Freezethaw is significant during winter and spring (Zhang et al. 2007, Wu et al. 2008).

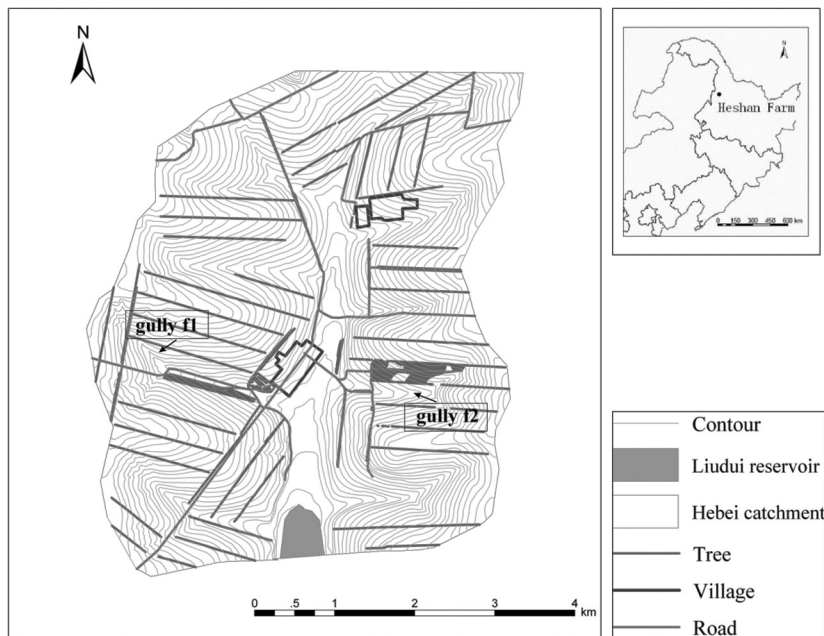


Fig. 1. Location and basic information of the study area and gullies

Two approaches for controlling gully erosion

The gullies appeared after the reclamation of the land for agriculture since 1960, and became a serious problem till 1990s. Therefore, the local government planed to control the gully erosion, and a program for controlling gully erosion was carried out during 1994–1996, which cost about 3 million yuan (about three hundred fifty thousand US dollar). Two approaches were adopted in the program, first approach is named as “Soil fill”, the gullies were buried with soil and fragment rock. After being compacted by machine, local people planted trees or grass on the surface of the infillings. Second approach is called “Vegetation cover”, the osiers and grass were planted at the bank and bottom of the gully to reinforce the site. In 1991, before the program started, the government had measured the length, width, depth and volume of all the gullies in the study area by using tape measures. We began to measure the gully by using differential GPS in 2003 and use ArcGIS to construct the gullies’ DEM (Wu & Cheng 2005, Wu et al. 2008). Each year we measure the gully one or two times until now.

Results

Soil fill

The “Soil fill” approach was adopted regarding Gully f1 (Fig. 1), and its volume was about 1300 m³ in 1991. It was buried during the program and grass was planted on the surface of infillings.

According to the field investigation in 2009, the location of f1 was protected by grass very well, and

only three small gullies were found in this place, and the total volume of the three gullies is only about 120 m³. It seems that the “Soil fill” approach is an effective approach to control gully erosion. However, we find a new gully 2–1 at the downstream of gully f1 (Fig. 2). This new gully is located in the bottom of the catchment, and developed very fast in last few years.

The change of sediment delivery may be the main factor to produce the new gully. According to former researches, erosion often occurred when the sediment content of the flow was lower than its transport capacity. Otherwise, the deposition happened (Foster 2005). After the gully control program, the original place of f1 was protected by vegetation very well, and the sediment yield from this place decreased, which made the sediment content of runoff much lower than its transport capacity, and increased the risk of erosion at downstream area of gully f1.

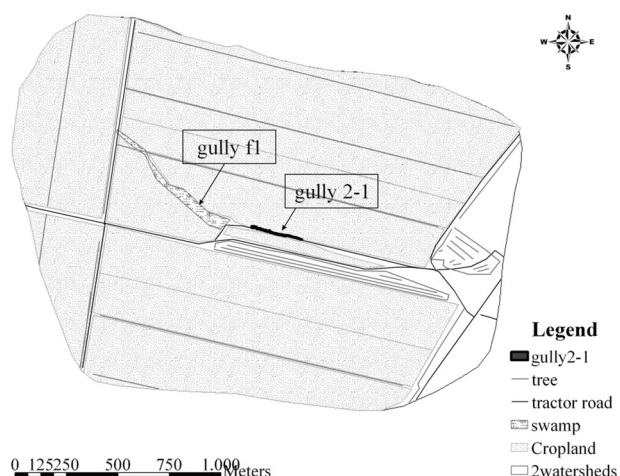


Fig. 2. Location of gully f1 and gully 2–1

Though gully erosion at the original place of f1 is very gentle now, volume of the new gully 2-1 is close to the gully f1. Furthermore, gully 2-1 still developed very fast from 2004 to 2009, and the average erosion rate was $136.12 \text{ m}^3 \text{ yr}^{-1}$. So at the catchment scale, this approach had a little effect on controlling gully erosion.

The new gully also affected the landuse of the catchment. After gully 2-1 appeared, an entire piece of land was divided into two pieces, and the agricultural machinery can not move across gully 2-1. Local government has to spend more money on building a new tractor road for mechanical tillage.

Vegetation cover

The “Vegetation cover” approach was adopted regarding Gully f2 (Fig. 1). Osiers and grass were planted on the bank and bottom of the gully. Now gully f2 is covered with osiers, grass and some wild species, especially the part of gully formed before the program to control gully erosion from 1994 to 1996, the vegetation cover of the part is over 90%.

Gully f2 now is the biggest gully in study area, and we began to measure it in 2006, the average gully erosion rate decreased about 20% after the gully controlling program, and from 2006 to 2009, the volume of gully f2 decreased nearly 190 m^3 . Generally, the “Vegetation cover” approach seems has good effect to control gully erosion. However, the headcut retreat of gully f2 is still obvious. Though the total volume of gully f2 was reduced during last 3 years, gully f2 was still suffering serious headcut retreat. In 2006, 8 new gully heads were found, and the headcut retreat of gully f2 was obvious from 2006 to 2009 (Fig. 3).

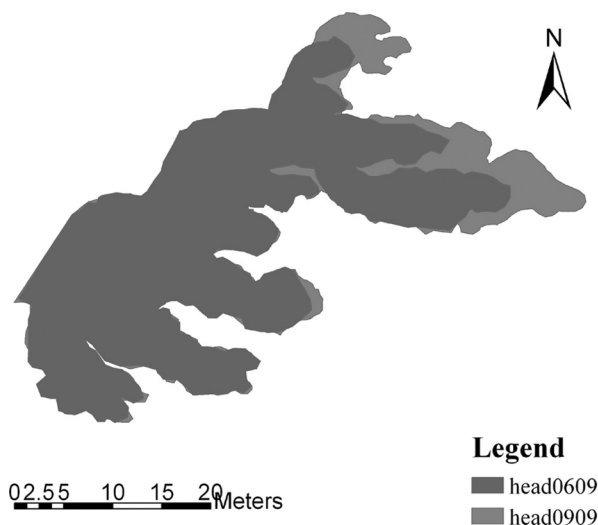


Fig. 3. Headcut retreat of the new erosion part of gully f2 during 2006 to 2009

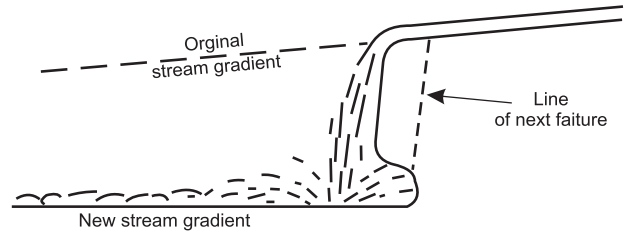


Fig. 4. Waterfall effect at gully head

The high rate of headcut retreat may be caused by waterfall effect (Fig. 4), which scours the soil where it lands, leads soil at this part to be eroded away, leaving the top soil overhanging. The top soils lose the support force from the bottom and tend to collapse.

The second factor may be due to the freeze-thaw process. Soil water freezes in winter which cause the reduction of granular interlocking within the soil, and generates cracks on gully bank. When the snowmelt runoff occurs in spring, the soil water content remains high level of gully bank and soil cohesion will decrease, and make the soil tend collapse from gully bank. “Vegetation cover” approach can not control the waterfall and freeze-thaw process, so it produces little effect on controlling headcut retreat.

Discussion

Generally speaking, these two approaches were not very successful in the study area, but we should learn some experiences from them.

There are two principles of gully control given by former researchers as follows: first, determine the cause of gully and take related measures. Second, restore the original hydraulic balance or create new conditions (Hudson 1995). According to our study, these principles were useful but not enough. As to the first one, we should not only focus on the cause of gully, but also the factors that accelerate gully erosion. Like the example of gully f2, local people knew that the extremely runoff event caused the gully development, and took the effective approach (“Vegetation cover”) to stabilize the part of gully formed before the program, this part now has high vegetation cover and the develop process is nearly stop. But they ignored the impact of the waterfall effect and freeze-thaw process, which intensified the headcut retreat, and leads to the quick development of the gully’s head.

The second principle only focus on the place which suffered gully erosion, but according to our study area, we suggest that a soil conservation program should consider the problem at catchment scale. Just like the example of gully f1, the “Soil fill” approach restore the original hydraulic balance of gully’s location, and vegetation protected area very well. However, local people ignored the impacts of

the downstream of gully f1, which produced a new gully, and caused high amount of soil loss and affected the landuse of catchment.

Conclusions

- 1) “Vegetation cover” approach is better to control gully erosion than “Soil fill” approach in this region.
- 2) “Soil fill” approach can protect the original place of gully erosion well, but this approach ignores the whole impact at the catchment scale, and may lead to new gully development.
- 3) “Vegetation cover” approach has little effect on controlling the headcut retreat.

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