ISSN:2372-0743 print
ISSN:2373-2989 on line
International Journal of Ground Sediment & Water
Vol. 02
2015

◆Research Paper◆

Erosion and Sediment Yield Time-Space Distribution Characteristics Research of Slope-Gully System Based On Simulated Rainfall

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Abstract： Using the automatic artificial rainfall system of MWR loess plateau soil and water loss process and control key laboratory, the researchers did simulation experiments of three different rainfall intensity to artificial simulation bare slope gully system, and analyzed erosion and sediment yield time-space distribution characteristics of slope-gully system. Results indicate that: erosion and sediment yield process of slope-gully system with the increase of rainfall duration showed a trend of increased volatility; the middle of gully slope and transition region of slope-gully system developed earlier and fastest-growing; ditch slope sediment yield and ditch slope runoff sediment concentration have the largest contribution to the export of slope-gully system runoff sediment concentration; in slope-gully system, lower-middle part and slope-ditch slope transition area are erosion prone areas; which shows that it is effective to control the erosion and sediment yield of loess plateau slope gully unit by adopting stress governance ditch and also measures of slope setting in practice.

Keywords: Slope-Gully System; Erosion and Sediment Yield; Runoff Sediment Concentration; Time-Space Distribution Characteristics

1 Introduction

Soil erosion has become a threat to modern society and sustainable agricultural development of global environmental problems, it can not only lead to the continued degradation of land quality, but also it is the main source of non-point source pollutants of water resources [1].Slope-gully system is the basic component unit of the loess plateau watershed and control soil and water loss, the basic management unit of the restoration and reconstruction of ecological environment, is the leading source of small watershed erosion and sediment yield at the same time. The erosion phenomenon and law of exploration, can provide slope gully optimized configuration

of soil and water conservation measures with scientific basis, for rehabilitation and reconstruction of ecological environment is of great significance [2]. Therefore, the slope-gully system in the Loess Plateau soil erosion has always been much attention and research experts.

In terms of runoff and sediment yield in the slope gully system, many scholars on the Loess Plateau sediment yield process studies carried out in different time-space scales [3-6]; The observation results Juying Jiao, etc show that the sheep ditch watershed in Shanxi between watershed gully slope accept to runoff erosion and sediment yield is 1.8 times that of the slope does not accept gap between runoff [7]; Based on the model of concept of self-organization by Jinren Ni, the development process of slope is simulated and the relationship between sheet erosion and rill erosion in slope erosion is analyzed. The influence of slope on the speed of the development of slope is also discussed[8];Peiqing Xiao used indoor artificial rainfall experiment method to study the influence of the evolution of the slope erosion on the sediment yield of the erosion and analyzed the contribution of different stages of gully erosion to the sediment yield of slope erosion[9].However, the study on the temporal and spatial characteristics of the vertical change of soil erosion and sediment yield is less, and the research results have a certain reference value for the identification of the erosion and development of slope gully system.

1 Materials and Methods

1.1 The slope-gully system model

The slope-gully system model is variable slope movable steel soil groove with 10m length and 1m wide.The device was composited with slope and gully, filled with Zhengzhou Mangshan loess and the slope and gully gradient respectively was 20° and 35°. According to the observation and analysis,the slope-gully system were broken up into one to ten(shown in Figure 1).

1.2 Experimental Design

Simulated with the typical rainfall which occurred on the Loess Plateau, Select the rainfall intensity was 66mm/h, 85mm/h and 120mm/h.Based on the basic stability of erosion, the rainfall lasted for 98min,60min and 56min. Before the test, the soil had been 5mm sieve, then layered filling and compaction. The filling thickness of each layer is 10cm, and the total filling thickness is 45cm and to control the density in the range of 1.20-1.25g/cm^3.

2 Experimental observation

During the experiment, muddy water samples was got every 2min, and including to extract the samples from different spatial positions with 100ml syringes, Take the

method of water and sediment density conversion to calculate the runoff and sediment yield and other parameters；At the same time,recording the surface erosion evolution by photographed every 2-4min .

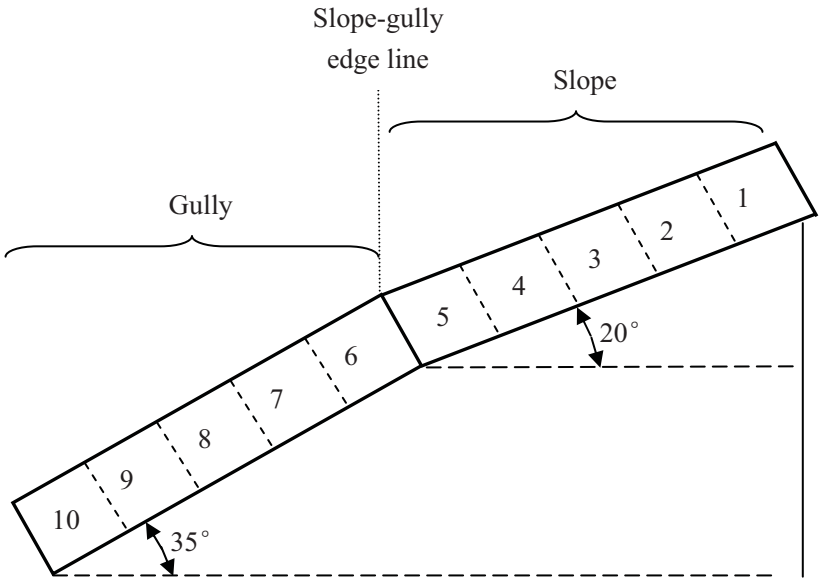

Figure 1 slope-gully system model and rainfall simulation system diagram

3 Results and analysis

3.1 Runoff and Sediment Yield Process Analysis

It is very important to study the dynamic changes of soil erosion and sediment yield in the study of the mechanism of erosion and sediment yield in the Loess Plateau. From experimental data, the sediment yield process curve of each rainfall was shown in Figure 2. The erosion sediment yield of slope gully system in different rainfall intensity increased with the increase of the rainfall time. As can be seen from the chart, the erosion sediment yield of slope gully system in different rainfall intensity was increased with the rainfall time goes on. Sediment yield process line of the rainfall intensity of 66mm/h is the lowest. With the increase of rainfall, sediment yield process have experienced 3 stages of “increase - volatility stable - Increase” phase. The first phase of the increase occurred within 30 minutes, the volatility stable phase occurred probably between 30 and 60 minutes, and the last increase phase occurred after 60 minutes later. The sediment yield process line of 85mm/h is as consistent as the line of the rainfall intensity of 120mm/h. In the pre 16min of rainfall, the sediment process line of 120mm/h is significantly higher than that of 85mm/h. Because rainfall at the beginning stage, the heavy rainfall that with greater energy and erosion force of raindrop splash erosion and surface erosion on the slope, leading to rainfall erosion and runoff sediment transport capacity increased. After 20min, rainfall runoff and sediment process line of 85mm/h and 120mm/h is no longer obvious, which shows that the surface erosion and development of slope gully system once started, more

than 85mm/h above the rainfall can lead to strong soil erosion.

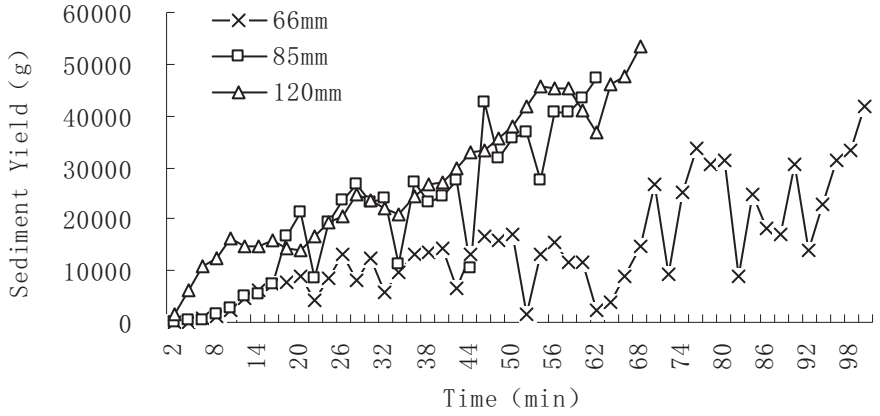

Figure 2 sediment yield process

3.2 Temporal distribution characteristics of sediment yield of slope-gully system

The total sediment yield of slope gully system is 65kg.In order to facilitate the analysis and comparison, the 66 mm/h rainfall simulation experiment eventually sediment yield as a reference, selected the stage of equivalent sediment under three kinds of rainfall intensity, and according to a period of 10min, the sediment yield in each period for the proportion of the total sediment can be count. It was shown in Figure 3.

When the sediment yield of 3 kinds of rain intensity reached about 65kg, the rainfall of 66mm/h had experienced 98min, while the 85mm/h and 120mm/h of rainfall only experienced 60min and 56min respectively. This indicates the rainfall more than 85mm/h has an acute process of sediment yield. From Figure 3, rainfall of 66mm/h sediment yield curve is relatively flat, while the 85mm/h and 120mmh rainfall runoff increased significantly with the increase of rainfall stage. Especially, the heavy rainfall intensity of 120mm/h, the slope gully system in the first rainfall period has occurred severe erosion and sediment yield. Followed by the 85mm/h rainfall, in the second, third rainfall stages, the proportion of the erosion sediment yield increased rapidly, and then the sediment yield ratio is close to that of 120mm/h. It is showed that for bare slope gully system, the erosion caused by rainfall of 85mm/h or more has been very intense, especially the high intensity rainfall of rainfall duration exceeds 30min.

3.3 Spatial distribution of sediment content of slope gully system

Sediment content of export runoff of slope gully system is the comprehensive response runoff sediment of slope and gully, combined with runoff sediment content spatial distribution characteristics of slope-gully system, can be reacted spatial distribution characteristics of erosion and sediment yield intuitively.

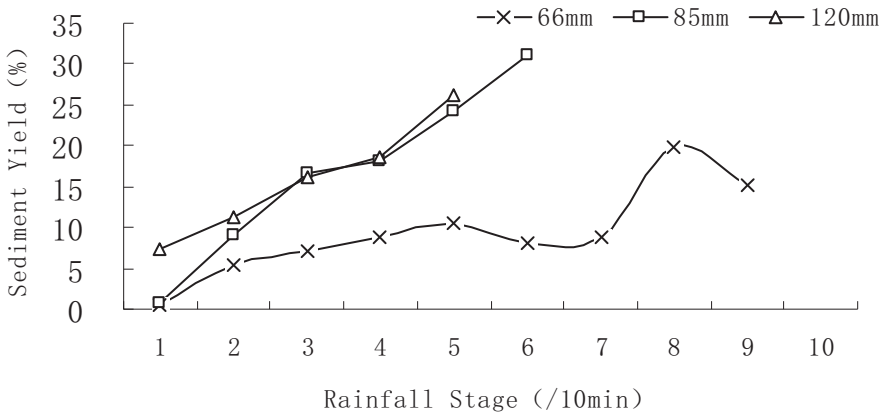

Figure 3 Distribution characteristics of sediment yield in each stage of rainfall

Six periods of rainfall distribution include sediment content of slope gully system(S_{p-g}), runoff sediment of slope(S_p) and runoff sediment of gully(S_g) in three kinds of rainfall intensity, which shown in Figure 4. Along with the rainfall duration increasing, the runoff sediment concentration tended to increase, especially for 85mm/h and 120mm/h rainfall is more obvious; The runoff sediment content of slope gully system is between runoff sediment content of slope and that of gully, S_p and S_g are analyzed for further regression(Table 1), it was found that under 85mm/h and 120mm/h rainfall intensity conditions, the relationship of runoff sediment concentration of slope gully system, S_p and S_g showed a positive correlation relationship. At 66mm/h rain intensity conditions, S_{p-g} and S_g was positively correlated, and negatively correlated with S_p. Further analysis of S_g and S_p coefficients are found, gully sediment concentration degree of effect on the slope-gully system runoff sediment concentration is stronger than the extent of slope runoff sediment concentration. As at 66mm/h rain intensity conditions, coefficient ratio of S_g and S_p is 1.36: 1,and in 85mm / h and 120mm / h rainfall intensity, coefficient ratios of S_g and S_p is 3.18: 1 and 29.35: 1, and it indicates that the greater the rainfall intensity, slope sediment runoff of slope gully system on export sediment increase stronger. Therefore, controlling runoff sediment concentration, taking into account the need to reduce the slope and gully runoff sediment concentration, especially in parts of the gully runoff sediment concentration.

Table 1 The relationship of sediment concentration between slope or gully and the whole system

雨强	The relationship of sediment concentration between the whole system(S_{p-g}) and gully(S_g)、slope(S_p)	Coefficient of S_g	Coefficient of S_p	correlation coefficient R
66mm/h	S_{p-g}=0.7873 S_g -0.5802 S_p	0.7060	-0.5802	R=0.9984
85mm/h	S_{p-g}=0.7060 S_g +0.2222 S_p	0.7060	0.2222	R=0.9912
120mm/h	S_{p-g}=0.8305 S_g +0.0283 S_p	0.8305	0.0283	R=0.9940

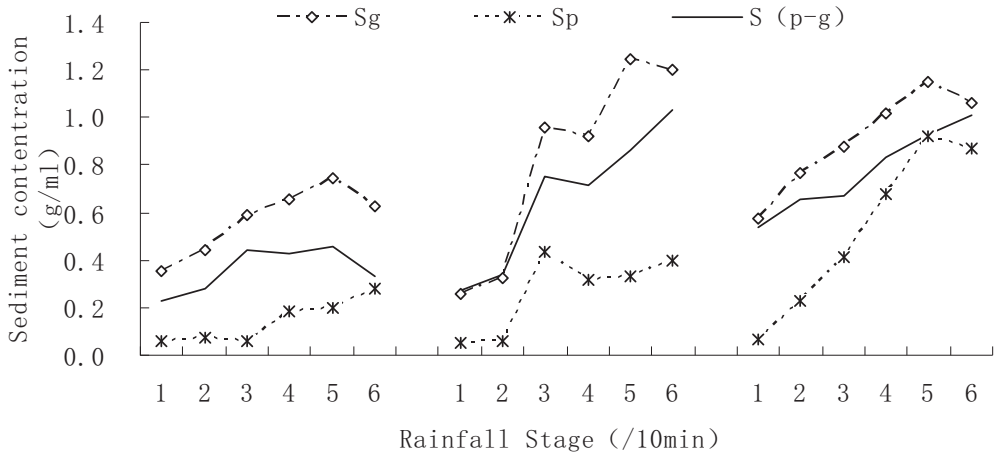

Figure 4 Spatial distribution of runoff sediment content of slope and gully

3.4 Spatial and temporal distribution of sediment concentration along the slope and gully

With the rainfall, runoff sediment concentration of each section also showed a trend of increased volatility, especially to gully part and the lower part of the slope is the most obvious. For 66 mm/h, with the extension of rainfall, the slope gully system development to the bottom of the slope section 5,while for 85mm/h and 120mm/h, erosion ditch in the slope gully transition zone developed to the 2 and 3 section of the slope in the middle of the slope. The rainfall of 85mm/h and 120mm/h on the surface morphology of the slope gully system is more serious. In the middle of the slope gully system and the transition zone of the slope gully system is the erosion prone region. It was shown in Figure 5.

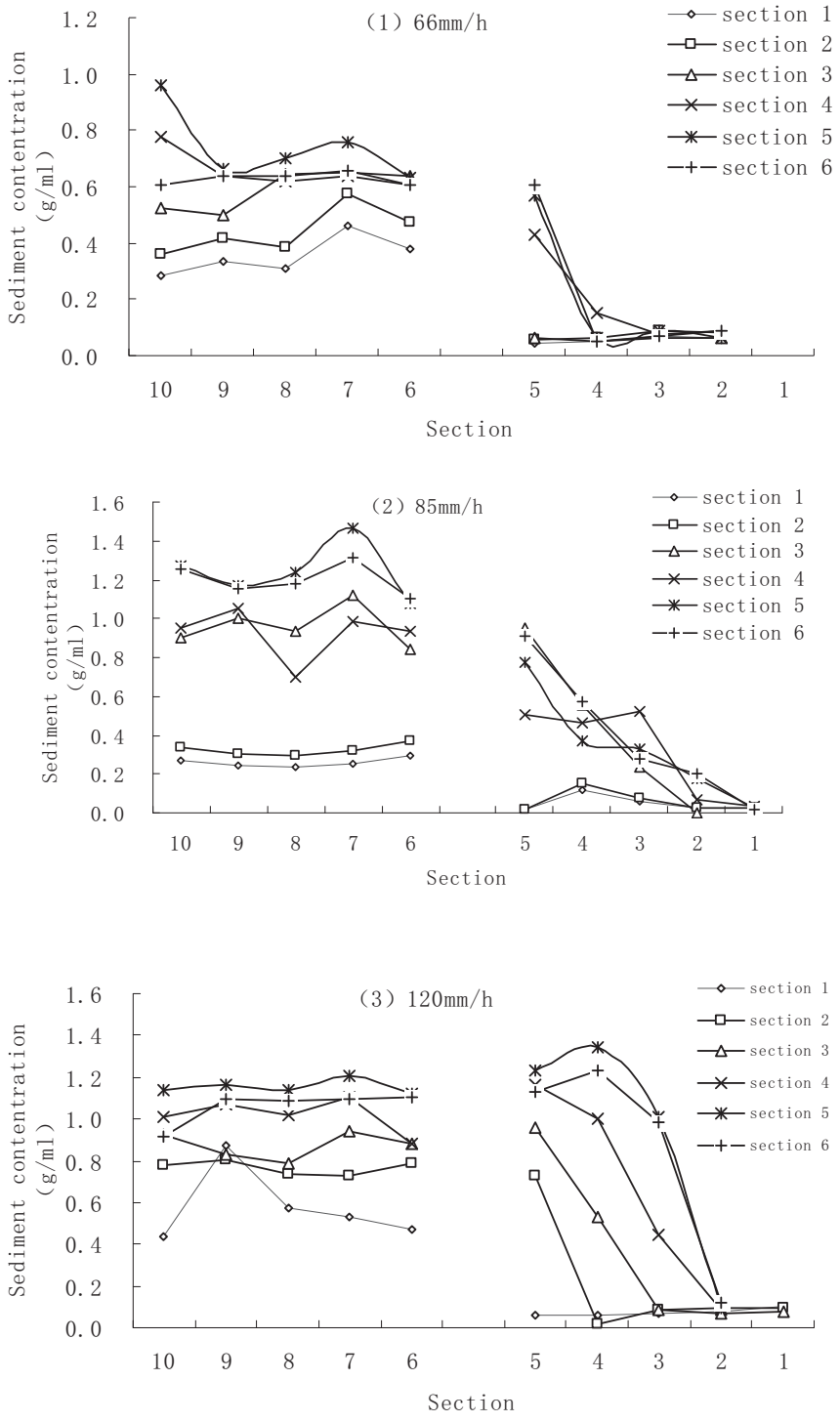

Figure 5 Temporal and spatial distribution of sediment content

4 Conclusions

Based on the rainfall simulation of the slope-gully system under the rainfall

intensity of 66mm/h, 85mm/h and 120mm/h conditions, Gotten the following conclusions:

(1) The high intensity rainfall has a strong destructiveness to the bare slope gully system, especially the rainfall duration is more than 30min of the strong rainfall

(2) In slope-gully system, the contribution of gully slope sediment and runoff sediment on the outlet runoff of slope gully system is maximum. Thus, should be a focus to reduce runoff sediment concentration on gully site when controlling runoff sediment concentration.

(3) In the lower part and the transitional zone of slope-gully system are prone to erosion area. In practice, the synthetical protection engineering and vegetation measures may be considered.

According to the results of this experiment, it is shown that in practice, the reasonable configuration of the slope treatment is adopted , which can effectively control the soil and water erosion in the Loess Plateau.

5 Acknowledgement

This research was supported by the central level scientific research institutes for basic R&D special business(No.HKY-JBYW-2014-08).

6 Reference

[1] Lei TW, Zhang QW, Yan LJ, etal. A rational method for estimating erodibility and critical shear stress of an eroding rill. Geoderma, 2008, 144: 628-633.

[2] XiaoPei-qing, Zheng Fenli, Yao Wenyi. Research Progress on Relationship of Sediment Yield and Erosion Mechanism Between Hill Slope and Gully Slope System. Research of Soil and Water Conservation,2004, 11(4):101-104.

[3] He Jijun,Gong Huili,Li Xiaojuan. Effects of rill development on runoff and sediment yielding processes. Advances in Water Science ,2014,25(1):90-97.

[4] Liu Junti, Sun Liying, Zhang Xuepei, A Study of Rill Evolution Process and Sediment Yield Characteristics on Loess Slope. Bulletin of Soil and Water Conservation, 2013,33(3):18-23.

[5] Ding Wenfeng , Li Mian, Zhang Pingcang , et al. Experimental study on the sediment yield characteristics in slope-gully system . Transactions of the Csae, 2006, 22(3):10-14.

[6] Wang Wen-long, Lei A-lin, Li Zhan-bin, Spatial distribution of runoff and sediment in the vertical belts of soil erosion chain in loess region of hilly and gully. Advances in Water Science, 2004,15(1):24-28.

[7] Jiao Juying, Liu Yuanbao, TangKeli.An Approach to Runoff and Sediment Generation of Gully and Intergully Land in Small Watershed. Journal of Soil and

Water Conservation, 1992,6(2):24-28.

[8] Ni Jinren, Han Peng, Zhang Jian. Characteristics of loess slope evolution based on concept of self-organization. Shui Xue Bao, 2002(1):6-9.

[9] Xiao Peiqing, Zheng Fenli,Wang Xiaoyong. Experimental Study on Erosion Pattern Evolvement and Sediment Process on Loessal Hillslopes. Journal of Soil and Water Conservation,2008,22(1):24-27.