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Reply on CC1

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Author comment on "Rill Erosion on Slope of Spoil tips: experimental study of runoff scouring erosion in multiple times" by Yongcai Lou et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-399-AC1, 2021

Thank for your comments on the article. We would like to respond to your comments in the following aspects.

Comment 1 It is indeed a interesting topic about soil erosion on spoil slopes that has experienced a long term study history. Rill erosion is also a old topic, and overall the core content is not so innovative.

Spoil tips, as anthropogenic landforms formed during development and construction project activities, have become an important source of new soil erosion. In recent years, soil erosion processes on the slope of spoil tips have received widespread attention (Peng et al., 2014; Zhang et al., 2015; Zhang et al., 2016; Niu et al., 2020; Guo et al., 2020; Li et al., 2020). Most of the studies on rill erosion have been based on field runoff monitoring plots, indoor soil tanks using 3D laser scanning technology or photographic photography to characterize the final erosion pattern of slope under a single rainfall or runoff scouring event (Fang et al., 2015; Tian et al., 2020), and also on the dynamic development process of rill erosion on sloping land(Qin et al., 2018; Shen et al., 2020). However, spoil tips, as a unique anthropogenic landform, have a platform-steep slope structure with a significant upslope inflow. This structure leads to the unique characteristics of steep-slope rill erosion in the spoil tips, which is different from the traditional gently sloping cultivated land rill erosion (Fig.2b and Fig.3). The rill development process and its erosion hydrodynamic characteristics of the slope of the spoil tips under the upslope inflow conditions are not yet known. This study is important and innovative in the sense that we combined field experiments with theoretical analysis to reveal some of the key characteristics controlling the dynamic development process of rill on the slope of spoil tips.

Comment 2 Most importantly, several of the experimental results were not reasonable.

Question1 Under a scouring test, the rill development characteristics in this study are obviously different from the actual rill network development. So, this is an unrealistic study, although it shows good results expression.

We disagree with these comments. The design and execution of the experiments are appropriate for the purpose of the study and represent real world spoil tips as we show below how our experiments relate to spoil tips in the Loess Plateau of China. The development of traditional sloping land rill head originates from the random strand flow formed in the middle and upper part of the slope under rainfall conditions. The rill starts from the head to converge in the lower part of the slope, and gradually forms the rill network and obvious rill erosion. The rill network is mainly dendritic in general (Fig. 1a). The middle and lower part of the slope is often seriously eroded (Fig. 1a and Fig. 2b). For the slope of the spoil tips, when there is no obvious upslope inflow, the distribution of rills is also random, and the rill network structure has some similarity with the natural slope (Fig. 2a). The above reasons are mainly due to the rainfall generating random strand flow on the slope, and under the random strand flow, the rill develops randomly. However, when there is upslope inflow, the rill network development is different from that under rainfall alone, which is indicating the influence of the upslope inflow on the evolution of rill (Fig. 1b and Fig. 3). It is worth mentioning that the development of rill above the slope in this paper is also random. At the outlet, the water flow is evenly distributed over the entire width of the runoff plot, however, when the water flows through the " soft" part of the slope, the rills are randomly distributed.

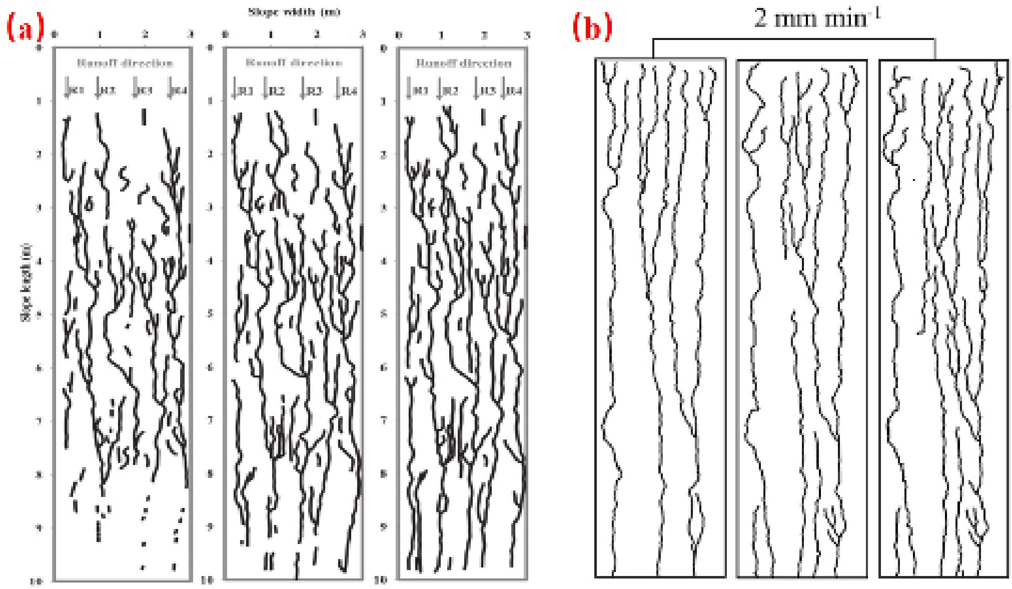

Figure 1 a: Spatial distribution of the rill network after three rainfall events at a rainfall intensity of 100 mm h^{-1} (Shen et al., 2020). b: Spatial distribution of the rill network in this study after three runoff scouring events at a inflow rate of 120 mm h^{-1}.

Fig. 2 a: Rill erosion on the slope of the spoil tips (when there is no obvious upslope inflow), b: Rill erosion on gently sloping cultivated land.

Figure 3 Field photo of rill erosion on the slope of the spoil tips (when there is a clear upslope inflow).

In addition, the flow production under rainfall conditions is a full-slope flow production, while the upslope inflow is a linear flow production. Under upslope inflow conditions, due to the attack of rills, it leads to further convergence of runoff, while the runoff in other parts is reduced or disappeared, thus scouring larger rills in the area where runoff converges, as in section 3.3 of this paper for the rill morphology evolution. Where runoff does not converge, the rill development stops.

Spoil tips are a unique man-made mound landform formed by production and construction activities, with a "platform-steep slope" structure. The development of the steep-slope rill head of the spoil tips from the large amount of runoff of the platform, and the rill is relatively stable along the development path of the steep slope, showing the overall distribution characteristics of relatively parallel rills from the top to the foot of the slope (Section 3.3 of the article) (Fig.3). Therefore, compared with the traditional sloping land rill erosion, the spoil tips rill erosion has special characteristics. The research on rill erosion and rill morphology evolution of the spoil tips are significant and address some important practical problems in.

Question2 Also, rill hydrodynamic parameters? To me Reynolds number, Froude number, shear stress, etc., they are all derived from river dynamics, can you guarantee that rill flow is similar to a river?

Rill erosion is caused by concentrated flow. Compared with waterflow in river channels, rill development occurs at steeper gradients, the rill flow depth is vastly different and the bank shapes are more irregular. However, rill flow is similar to flow in river channels in terms of sediment transport and deposition (MOSS et al., 1979). Hence, fundamental theories of streams and rivers can be applied to rill flow, and the corresponding methods and governing equations can also be used in studies of rill flow hydraulic characteristics until a more systematic and well-developed theory for rill flow hydrology is available. In addition, the rill network is the prototype of the water system development, and is also a microcosm of the water system (Raff et al., 2004). Meanwhile, variables used to characterize flow dynamics can also be used to study rill erosion according to the selfsimilarity theory (Peng et al., 2015).

The descriptions of hydrodynamic parameters in the existing soil erosion studies have been based on the parameters of river dynamics, indicating that they have great potential to be used in slope runoff erosion, which can reflect the soil erosion characteristics and reveal the soil erosion mechanism to a certain extent(Shen et al., 2016; Yang et al., 2020). The application of slope erosion hydrodynamic parameters has a long history. For example, the prediction of soil erosion using simple hydraulic indicators, which are mainly empirical models because they are obtained by looking for the hydraulic indicators which are most correlated to the measured soil loss in statistical terms (KNAPEN et al., 2007). Hairsine and Rose (1992) established a rill erosion model based on runoff power. In the WEPP model, when the sediment concentration of the rill flow is less than the sediment transport capacity and the runoff shear stress of the rill flow is greater than the critical shear stress, the rill erosion is dominated by denudation. The expression of rill erosion rate is□

$$\frac{dG}{dx} = D_f + D_i$$

$$D_f = D_c\left(1 - \frac{G}{T_c}\right)$$

$$D_c = K_r\left(t_f - t_c\right)$$

Where G is the sediment transport amount (kg·s^{-1}·m^{-1}), Df is the rill erosion rate(kg·s^{-1}·m^{-2}), Di is the interrill erosion rate(kg·s^{-1}·m^{-2}), Dc is the denudation rate of rill flow(kg·s^{-1}·m^{-2}), Tc is the sediment transport capability of rill flow(kg·s^{-1}·m^{-1}), Kr is the soil erodibility parameter of rill□tf is the runoff shear stress (Pa), tc is the critical shear stress (Pa).

In summary, this paper applies the hydrodynamic parameters to the study of slope rill erosion of the spoil tips with certain applicability and reference.

Question3 they are the derived from the river dynamics, you can ensure that the rill flow is similar with river? Also, there are several rills on a slope (Fig.1), so how did the the rill hydrodynamic parameters obtained? flow velocity of each rill on a slope was measured? and then how did you analysis the data? can it represent the rill flow dynamics? This is not credible.

The runoff velocity measurement scheme is adjusted according to the process of slope erosion rill development.

Runoff velocity were measured for the location of obvious strands of flow on the slope before the appearance of rill on the slope. After the rill formation of the slope, if there were more than one rill in the observed slope section, the runoff velocity of the slope section was represented by measuring the runoff velocity of each rill and calculating the average value. It should be noted that with the increase of duration and scouring times, due to the effect of headcut erosion, downcut erosion and bank landslip, resulting in changes in the rill network and runoff flow path, some rills are not measured for flow velocity when there is no longer runoff in the rill. The average value of the runoff velocity of the four observation sections is used to comprehensively characterize the runoff velocity of the slope (Tian et al., 2017). Due to the shallow runoff depth of the cross-section during the whole test, the error of direct determination is large, so the average runoff depth of the slope is calculated according to the empirical formula to obtain. Other hydrodynamic parameters are obtained based on the average runoff velocity and average runoff depth, which are used to characterize the hydrodynamic properties of the rill flow.

Comment 3 Rainfall test or natural rainfall study is a good method for understanding soil erosion mechnism of spoil slopes, because it can represent the actual process of rill developemnt on a spoil slope.

Thank for your suggestion, we agree with the point you mentioned. Rainfall is the main driving force in the field where there is no obvious up-slope runoff. The use of simulated rainfall and natural rainfall tests is optimal for studying rill development in this case. However, under field conditions, the runoff collected by the compaction platform of spoil tips is an important factor causing slope scour erosion and accelerating erosion of engineered landscapes (Zhang et al., 2016). The infiltration rate of the platform formed by heavy mechanical rolling is significantly reduced. Under rainfall conditions, the platform produces large concentrated runoff preferentially over the slope, and concentrated runoff rapidly flows along the edge of the platform to the steep slope, thus causing severe slope erosion. Therefore, the runoff from the platform is the main driving force for the slope erosion of the spoil tips. However, it should be noted that the rainfall also plays an important role in the rill erosion on the slope of spoil tips. We will consider a combination of rainfall and runoff in the later experiments to better and more realistically reproduce the field phenomenon.

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