MATURITY PROCESS OF RILLS

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INTRODUCTION

Rills are probably the smallest channel units occur on overland. The shearing action of the flowing runoff in rills, headcuts, as well as sidewall slumping provides additional sediment to the total sediment yield. Many factors have been identified and considered to be associated with rill development. These factors include soil texture, runoff volume, slope gradient, slope length, as well as physical and hydrologic properties of soils. Due to the complex interaction between factors, it is rare to find similar replicate of rill morphology, nor rill hydraulics, in the fields.

Two stages are involved in the life span of a gully (Sidorchuk, 1999). They are (1) active and (2) stable stages. Kosov et al. (1978) found that the active stage, brief and rapid progressive, constituted only 5% of a gully's life span. However, more than 90% of the gully length, 60% of the gully cross section, and 35% of the gully volume was formed in the first stage.

Sidorchuk (1999) proposed dynamic and static models to portray gully's two stages. Dynamic model was built to predict the rapid changes of gully morphology in the first stage of gully life span; whereas, static model was created to calculate final morphometric parameters of stable gullies.

Faulkner et al. (2004) hypothesized that translocation of mobile cations; particularly sodium being responsible in determining the location and subsequent enlargement of micro-pipes and rills. From the viewpoint of micromorphology, Faulkner et al. suggested that rills initiated after infiltration.

Most of the studies that previously addressed are related to rill development after incision. The objective of this study is to visually document the rill development during its early stage of incision so that processes associated with rill maturity can be addressed.

METHODS AND MATERIAL

Rainfall Simulator and Soil Box

This study was conducted in the rainfall simulator building situated in National Pingtung University of Science and Technology. The effective fall height of the rainfall simulator is 15m. The hypodermic syringe array formed by syringe needles in 20mm interval produces drop size distribution similar to that measured locally under natural rainstorms. The kinetic energy of simulated rain reaches 95% of that measured under natural rain with similar intensity.

Soil box was made of plywood, and it measured 3m long, 3m wide, and 0.5m in depth. Small holes were drilled in 50mm interval at the bottom plat of the soil box to facilitate free drainage. The soil used for this study was classified as silt loam. It was sieved to 2mm then left for air dry for at least a week.

Soil was remolded in the soil box layer by layer and a25kg concrete roller was used to compact the remolded soil at least 10 transacts along and across the slope. Total of 9 replicates was performed with rainfall intensity and slope gradient set at 120mm/h and 30%, respectively. Soil was discarded at the end of each run, and new soil was prepared.

Image processing

Still photos were taken every minute during a 60-min experiment run. PhotoImpact was used to post-process the still photos by adjusting the brightness to 60, contrast to 10, white-balance , and color temperature to 10,000 to enhance the rill patterns (Figure 1). The finished photos were digitized along the outskirt of the rills, and the digitized images were then displayed on a monitor in time sequence so that the progress of rill development could be followed.

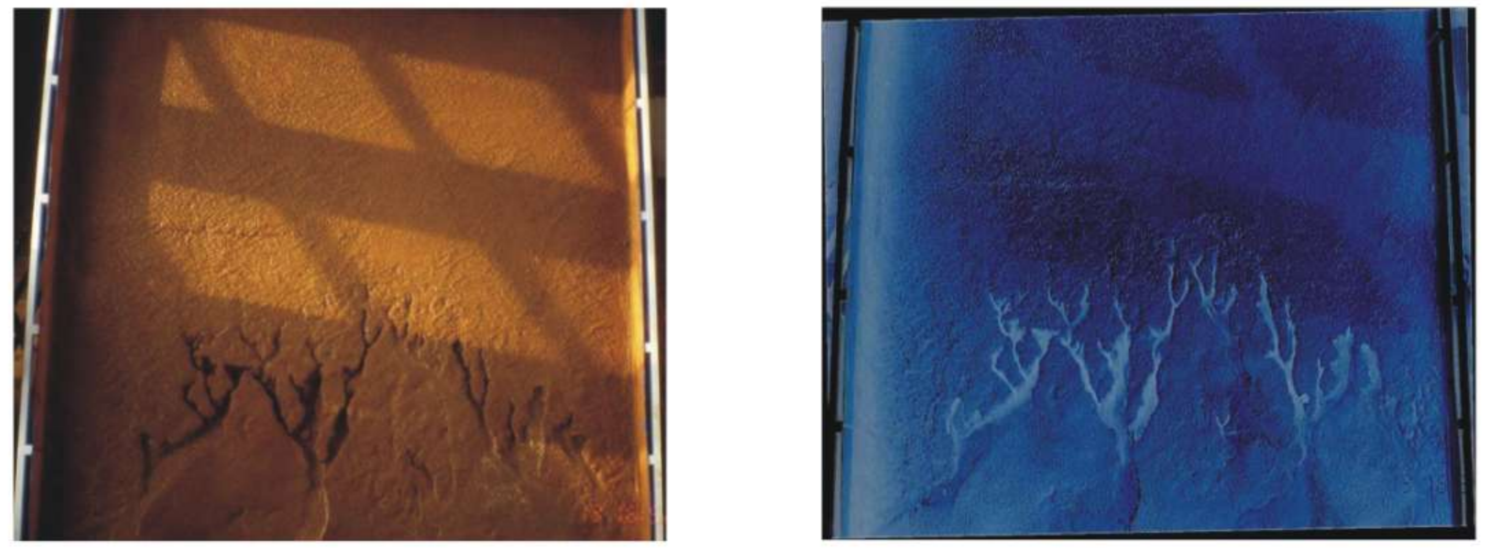


Figure 1. Pre- (L.) and Post- (R.) processed Images of Rill Development.

RESULTS AND DISCUSSION

Proceed from Raindrop Impact to Rills

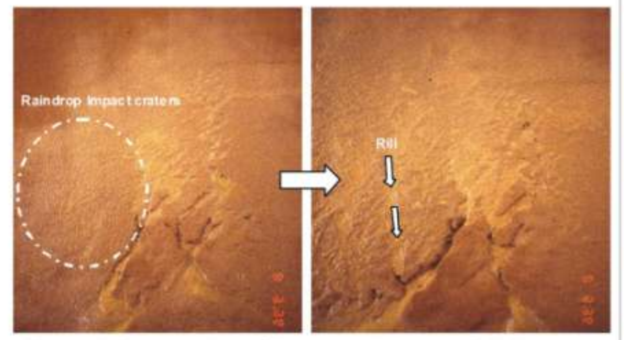


Figure 2. Proceeding of Raindrop Impact to Rill Incision.

Action of raindrop impact initiates the detachment process of erosion. The random occurrence of raindrop impacts creates an array of ripples on soil surface which later becomes deposition ridges as that shown in Figure 2.

For less cohesive soil like the one prepared in this study, we found that sediment deposited in the circumference of impact craters remained oversaturated with shining appearance which was the result of light reflection on wet crater crowns. Continuous impacts shortly after were able to rearrange the configuration of crater array. Excess moisture from crater crowns started releasing downslope and caused flow to concentrate. Rill incision began as that shown in Figure 2.

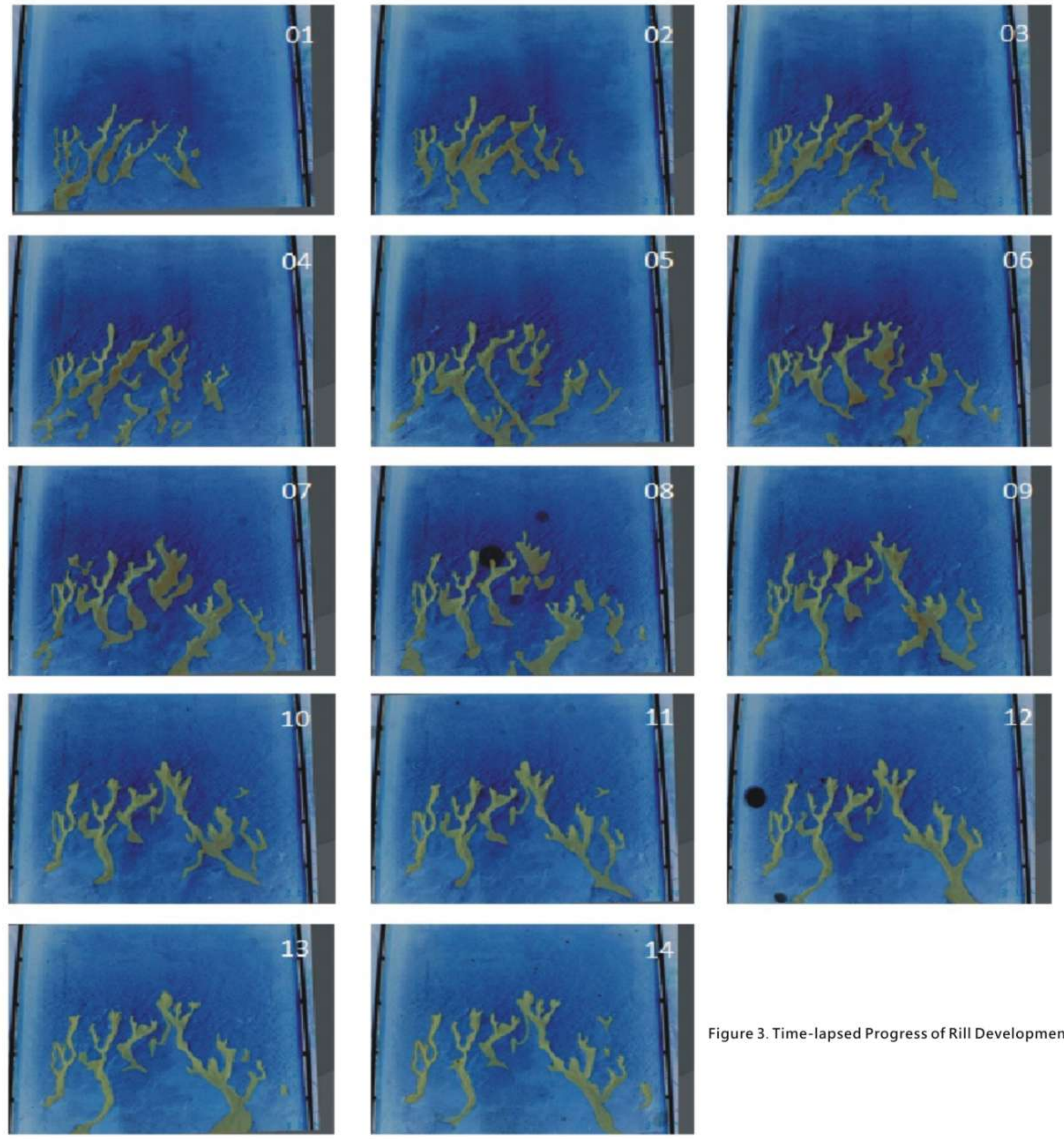


Figure 3. Time-lapsed Progress of Rill Development.

Progress of Rill Development

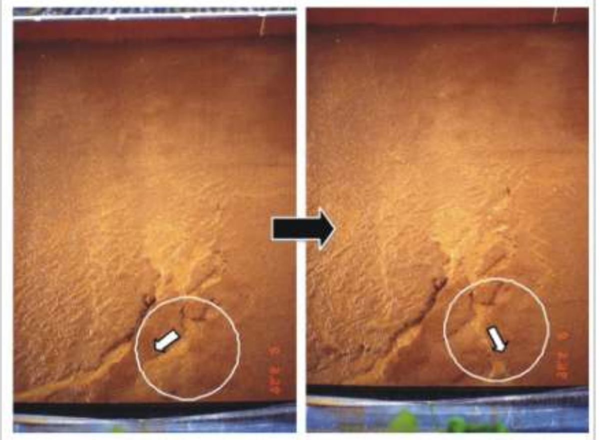


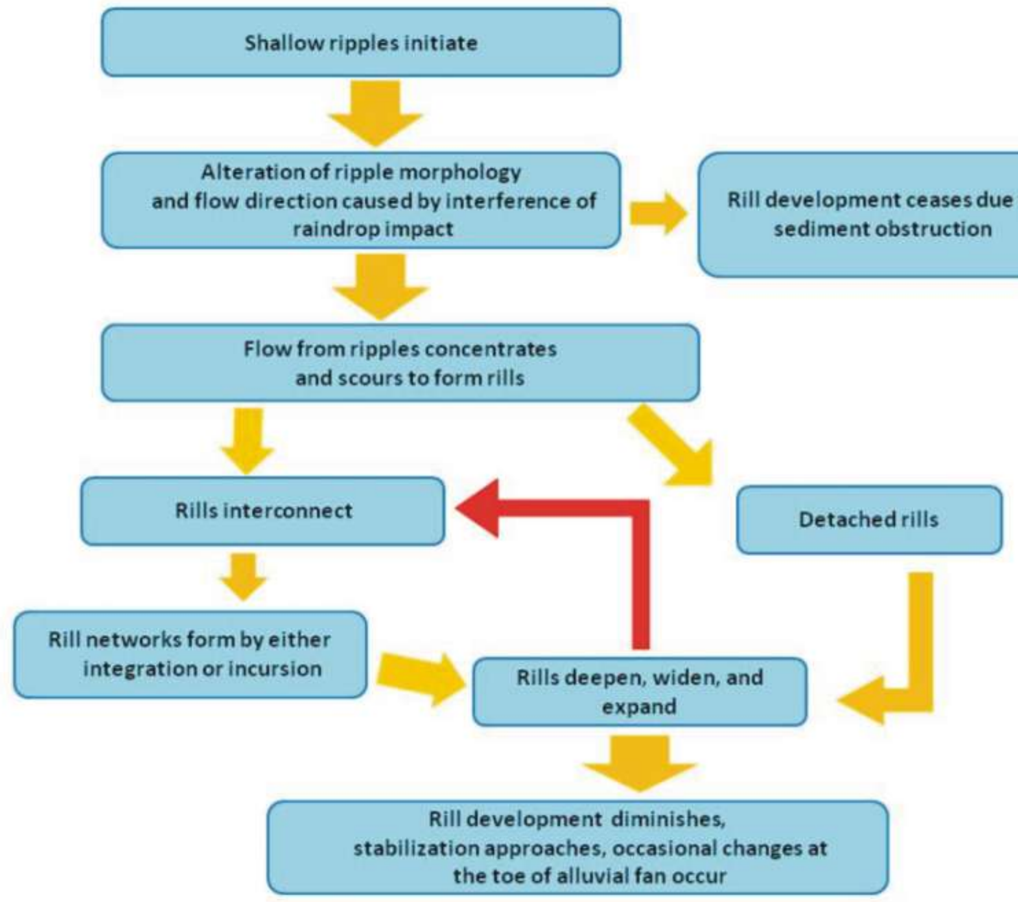
Figure 4. Change of Flow Route Caused by Sediment

Figure 3 consists of a series of post-process photos superimposed by digitized rill patterns. Photos were arranged from left to right and from top to bottom in time sequence. Therefore, Figure 3 chronicles a slot of time frame during the rill development.

There are a couple of distinct features associated with rill development in the first three photos; numbered 01 to 03 respectively.

- Veer of rill 'trunk' from southwest to south then back to southwest.
- Rill 'trunk' enlargement and tributary connection.
- Oversaturation of overland surface and tributaries banks.
- Bank collapse at oversaturated tributary which broadens the rill.

Rill Germination



Rill-networking is germinating from frame 04 to frame 08 in Figure 3. During this period of rill development, numbers and scales of rills are continuously increasing. Detached rills remain active which suggests that neither processes of detachment limiting nor transport limiting exist during the rill germination.

Rill Network Formation

Time-lapsed images reveal the pseudo-maturity of the rill while the depth of the rill reaches to a certain limit as that shown from frame 09 to frame 14 in Figure 3. Sediment supplied from upslope determines the fate of rills, which could go either way, disappearance as the consequence of transport limiting or enlargement as the result of supply limiting.

Maturity and scope of rills was found to be controlled by the confluence of rills. The outside rill branches from two adjacent rill networks that under simultaneous development will eventually meet at some points along the boundaries of drainage basins.

Figure 5 demonstrates the incursion of rill network on the left that having greater drainage basin than the rill network on the lower right. Two rill networks integrate into one unit after incursion and create a larger rill network.Integration of rill networks does not ensure a stable development herein; especially during the early stage of rill maturity.

Rills having higher order in rill network begin to shift between transport limiting and supply limiting; whereas, rills having lower orders in rill network remain relatively stable. It appears that both cross sections and orders come to a halt until emergence of sub-surface runoff or rill bank slump whichever occurs first. Therefore, rill systems with higher orders may not assure greater sediment contribution as compared to rills with lower orders.

Figure 5. Example of Rill Network Incursion.

CONCLUSION

Time-lapsed photos taken during this study have provided experiment observations which suggest that a loop; a less deterministic one; has a tendency of self-repeating until a pseudo-stability is reached.

- The emergence of sub-surface runoff at the outskirt of raindrop impact crater array might be one of the possible causes that assist in the proceeding of raindrop impact to rill incision transformation.
- Continuous occurrence of miniature mass slumping, sediment clogging, flow route changing, miniature 'sediment dam breaking', and wiping off the sediment residues by concentrated flow is beyond the conceptual idea of detachment and transport capability limits in interrill sediment delivery process.
- Rills having higher order in the network are constantly under the shifting process between transport- and supply limiting; whereas, rills having lower orders remain relatively stable until emergence of sub-surface runoff or rill bank slump whichever occurs first.

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