# PROPOSED METHODOLOGY TO QUANTIFY EPHEMERAL GULLY EROSION

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## 1. Introduction

Ephemeral gully erosion is the main source of sediment from the agricultural landscape, unfortunately, it has been overlooked in traditional soil erosion assessment (Poesen et al., 2003). Since an ephemeral gully, by definition, can be easily alleviated or filled by normal tillage, the difficulty in making the ephemeral gully erosion assessment is the lack of well-defined channel morphology such as classical gullies and river channels. Additionally, the width and depth of the ephemeral gully are too small (+/- 0.5 m) to be detected by general topographic surveying and mapping.

There are two general approaches used in assessing ephemeral gully erosion. The widely known and used Ephemeral Gully Erosion Model (EGEM) and some current process-based water erosion model (e.g., WEPP, Nearing et al., 1989) simulate the gully as a concentrated flow channel, hence, requires input for channel geometry and length (Woodward, 1999; Nachtergaele et al., 2001; Capra et al., 2005). This model may be useful once the gully has been formed. The other approach uses a topographic threshold concept based on extensive field surveys on existing gullies to back track significant topographic attributes contributing to gully initiation. For the second approach, critical slope steepness and contributing area relationship has been found for ephemeral gully initiation (Vandekerckhove et al., 1998; Vanwalleghem et al., 2005). Despite the differences, both approaches focus on hydraulic shear stress as the main factor without considering the subsurface hydrology of the soil which may have inherently caused ‘weak’ spots on the landscape for gully initiation.

Research conducted in the Belgian loess belt identified different hydrologic conditions for summer vs. winter gullies with surface shear under intensive storms being the main driving factor for the summer gully and profile saturation or subsurface flow the cause for winter/spring gully development (Nachtergaele et al., 2001). From a geomorphic point of view, if ephemeral gully is the transition between a hillslope and a permanent drainage channel, it can be argued that both surface and subsurface flow may also converge at locations that become initiating points of the gullies.

In this paper, we report our proposed methodology to include subsurface hydrology to develop a landscape model for ephemeral gully erosion assessment.

## 2. Research Objectives and Methodology

The overall objective of the proposed research is to identify and quantify landscape attributes and hydrologic conditions that can be used to assess hillslope seepage and ephemeral gully erosion. We propose to use three different methodologies to study ephemeral gully development, i.e., 1) laboratory rainfall simulation to quantify seepage and hydraulic shear effects on rill or gully initiation; 2) digital photogrammetry from low altitude aerial photography to quantify ephemeral gully development; 3) topographic threshold based ephemeral gully erosion model with subsurface hydrology.

### 2.1. Laboratory Experiments

The laboratory study is designed to quantify the critical conditions for rill or ephemeral gully initiation under surface flow and subsurface seepage. The process we are interested in is the initial down-cutting from an un-eroded surface instead of channel deepening, widening or sidewall sloughing on existing rill or gully channels. Prior research showed that seepage conditions greatly enhanced rill erosion (Fig. 1). The proposed laboratory study will further place the seepage induced erosion in a landscape context by quantifying the critical drainage area relationships (Kirkby, 1994) which contain terms such as rainfall intensity, soil infiltration, slope, critical shear stress, internal friction and effective cohesion.

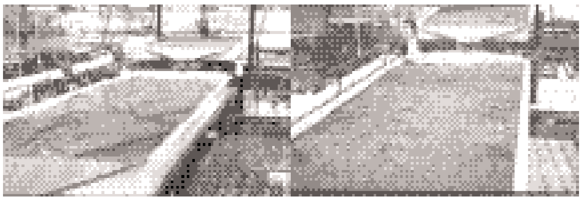

**Fig. 1.** Severe rilling under seepage (left) in contrast to surface scour (right) for the same soil, slope and rainfall.

Three experiments are planned. Experiment 1 will be conducted in small soil boxes (0.3 m (w), 0.45-m (l) and 0.3-m (d)) set to 5% slope and with free drainage, -10cm, -5 cm water table (tension or drainage) and 0 cm (saturation) and +5 cm, +10 cm (seepage) gradient and exposed to 25, 50 and 75 mm/h simulated rainstorms for rainfall dominated erosion assessment.

Experiment 2 will use a mini-flume, measuring 0.2m (w), 1m (l), 0.1m (d) with the same hydraulic gradient and slope treatments as the rainfall study, to quantify concentrated flow detachment under 10, 20, 40, and 80 l/min inflow. These two experiments will produce adjustment functions

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for soil erodibility and critical shear stress under saturation and seepage conditions.

Experiment 3 will be conducted in a multiple box system that consists of three soil boxes in an up and down slope cascade each measuring 1.2 m (w) by 1.8 m (l), 1.2 m (w) by 5 m (l), and 0.6 m by 4.5 m (l) with 0.3m (d) for all three boxes. Since each box has separate rainfall simulator and seepage/drainage control, we can simulate different upslope contributing areas with different levels of run-on and adjust slope and surface hydraulic gradient (seepage vs. drainage) at the down slope test box to quantify the critical area for rill or gully initiation.

## 2.2. Low altitude digital photogrammetry

The analysis of time lapsed aerial photos or DEM to quantify gully erosion has been well documented, especially aided by geo-spatial data processing techniques in recent years (Martinez-Casanovas, 2003). These studies are mainly on well-developed gullies with depths in the order of 1 to 10 meters or greater. There is still a need to develop an accurate and rapid tool to assess rill or ephemeral gully erosion in the order of 0.5-1.0 m wide and 0.1 to 0.2 m deep in cultivated fields.

Using low cost digital cameras to acquire 8 to 10 mega pixel images has made photogrammetry a much more feasible technique to generate DEM for gully erosion assessment. Although a remote controlled blimp has been successfully used to acquire low-attitude photo images, it is not a technique that can be easily adopted (Ries and Marzolff, 2003).

We have made progresses in developing software that will merge overlapping digital photos with ground control points to estimate DEM. Planned work include 1) testing this photogrammetry software and comparing generated DEM's with laser scanned DEM's in meter size areas; 2) testing different unmanned aerial vehicles (UAV) to acquire photographs at 10 to 100 m altitude; 3) testing alternative ground-based photographic approaches .

## 2.3. Modelling Ephemeral Gully Erosion

The proposed modelling approach will first to analyze the subsurface factors for potential hillslope seepage. This subsurface hydrology analysis will combine detailed digital elevation model, soils database, topographic attributes, i.e., slope shape, length and steepness, upslope contributing area, and soil profile properties to develop a spatially distributed data layer for potential hillslope seepage and ephemeral gully erosion.

Soil profile properties to be evaluated for seepage potential include soil texture and depth to impervious horizon. The seepage potential map will be superimposed onto the landscape threshold model that uses localized slope steepness and contributing area to account for the surface hydraulic shear potential for a combined surface and subsurface hydrologic model for ephemeral gully initiation. Climatic factors, such as rainfall amount and distribution and potential evapotranspiration will be used to quantify climatic potential for summer storm-driven (surface shear) vs. winter/spring soil saturation controlled ephemeral gully initiation. This spatially distributed, process-based seepage and ephemeral gully erosion model will be compared to field observations.

The field observation will be initially focused at central Indiana in conventionally cultivated fields. Ephemeral gullies will be mapped for their channel geometry using a differential GPS total station as well as the aerial photogrammetry technique once it is developed. The mapping will be done in early spring before spring cultivation and in the fall after harvest. Any tillage operation that may obliterate the ephemeral gully will be recorded. For each ephemeral gully, geo-referenced soil probing will be conducted in the contributing area, with 1-2 m grid near the gully channel and 20-50 m grid for the rest of the area, to obtain depth to impervious horizon data.

The field survey will be used to create a data layer and compared to the same attributes derived from available DEM and soil survey map. We plan to test the topographic threshold concept for the combined surface-subsurface hydrology model for ephemeral gully initiation. Where gully channels already exist, we plan to test the EGEM and develop a process where both topographic threshold and EGEM-based channel hydraulics can be combined in the ephemeral gully erosion model. Since ephemeral gully is a feature resulting from processes at the 2-dimentional landscape, we anticipate the outcome will be incorporated into a process-based model such as the Water Erosion Prediction Project (WEPP) model.

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