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How fast do gully headcuts retreat?

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Gullies can be a dominant sediment source at field and catchment scales. Over the past decades, several studies have been conducted that quantify gully headcut retreat (GHR) in different environments. Although this led to important site-specific and regional insights, the overall importance of this erosion process or the factors that control it at a global scale remain poorly understood. This study aims to bridge this gap by conducting a meta-analysis of measured GHR rates worldwide.

Through an extensive literature review, GHR rates for ca. 900 individual actively retreating gullies (comprising a total measuring period of > 19 000 years) from more than 50 study areas worldwide have been compiled. Each GHR rate was measured by means of repeated field surveys and/or analyses of aerial photographs over a period of at least one year. The collected data shows a very large variability, both in terms of gully dimensions (cross-sectional areas ranging between 0.11 and 816 m^2 with a median of 4 m^2) and GHR rates (ranging between 0.003 and 47 000 m^3/y with a median of 2.2 m^3/y). Linear GHR rates vary between 0.01 and 70 m/y (median: 0.82 m/y).

By means of statistical analyses for a subset of 689 gullies with a known contributing area, we explored which factors are most relevant in explaining the observed 6 orders of magnitudes of variation in volumetric GHR rates. Results show that measured GHR rates are significantly correlated to the runoff contributing area of the gully (r^2 = 0.13) and the average rainfall depth on a rainy day (i.e. the long-term average annual rainfall depth divided by the average number of rainy days; r^2 = 0.39). Combined, these two factors explained 57% of the observed variability in average GHR rates. Other factors (e.g. land use or soil type) showed no significant correlation with the observed GHR rates. This may be attributed to the uncertainties associated with accurately quantifying these factors. In addition, a large part of the remaining unexplained variance may be due to measuring periods that are too short to fully capture the large temporal variability that are typical for GHR rates. This is illustrated by the fact that catchment area and average rainfall depth on a rainy day explain nearly 70% of the observed variation in GHR rates for gullies monitored over a period of at least 20 years. These findings have important implications for models that predict gully erosion rates.

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