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Spatial variation of gully density and morphology and their controlling factors at a regional scale: a case study for the Chinese Loess Plateau

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Gully erosion is a major cause of land degradation in many regions worldwide. Recent research shows that the challenges posed by gully erosion are likely to further increase as a result of climate change and increasing land use pressure. Nonetheless, our understanding of this process remains limited in many ways. While numerous studies have focused on the occurrence and morphology of gullies at local (catchment) scale, relatively little research has explored their spatial variations at regional to continental scales. As a result, the factors controlling the density, size and morphology of gullies at such scales remain poorly understood. This is especially the case for the role of climate/weather conditions. Here we aim to advance our understanding on this topic by studying gully densities and gully morphology in the Chinese Loess Plateau (CLP), a region severely affected by gully erosion.
We selected five representative catchments in the CLP that are relatively similar in size (7-30 km²), topographic context, soil characteristics and land use but represent a large gradient in rainfall conditions. We mapped 2511 gullies in these catchments, using Pleiades-1B (panchromatic resolution at 0.5 m) and WorldView-3 images (panchromatic resolution at 0.31 m). For each of the gullies, we calculated a range of morphological parameters including the gully length, width, surface area, length-width ratio and shape index. Next, we explored to what extent differences in gully density and morphology are correlated to contrasts in rainfall and other environmental factors.
Overall, the gullies showed large variations in gully length (2.1-308 m, average 38.1 m), width (1.3-87 m, average 11.5 m) and density (0-4.8 km/km², average 2.3 km/km²). Gully densities showed a negative correlation with rainfall amounts. This is likely partly attributable to feedbacks between rainfall amounts and vegetation cover. However, also contrasts in rainfall intensity and regime likely play an important role. Also variations in gully width appear strongly correlated with rainfall patterns (with more humid catchments resulting in overall wider gullies). Surprisingly, gully lengths (a first indicator of gully headcut retreat) showed no clear correlation with rainfall patterns. Overall, our results indicate that contrasts in rainfall regime are crucial to understand gully erosion

dynamics at regional to continental scales. This is true for their initiation but also for their subsequent expansion (and especially gully widening). These findings have important implications for the development of models aiming to predict gully erosion at regional to continental scales.