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A first data-driven gully head density map of the world

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Gully erosion has been recognized as a main driver of soil erosion and land degradation. While numerous studies have focussed on understanding gully erosion at local scales, we have very little insights into the patterns and controlling factors of gully erosion at a global scale. Overall, this process remains notoriously difficult to simulate and predict. A main reason for this is that the complex and threshold-dependent nature of gully formation leads to very high data requirements when aiming to simulate this process over larger areas.

Here we help bridging this gap by presenting the first data-driven analysis of gully head densities at a global scale. We developed a grid-based scoring method that allows to quickly assess the range of gully head densities in a given area based on Google Earth imagery. Using this approach, we constructed a global database of mapped gully head densities for currently >7400 sites worldwide. Based on this dataset and globally available data layers on relevant environmental factors (topography, soil characteristics, land use) we explored which factors are dominant in explaining global patterns of gully head densities and propose a first global gully head density map.

Our results indicate that there are ca. 1.7 to 2 billion gully heads worldwide. This estimate might underestimate the actual numbers of gully heads since ephemeral gullies (in cropland) and gullies under forest remain difficult to map. Our database and analyses further reveal clear regional patterns in the presence of gullies. Around 27% of the terrestrial surface (excluding Antarctica and Greenland) has a density of > 1 gully head/km², while an estimated 14% has a density of > 10 gully heads/km² and 4% has even a density of > 100 gully heads/km². Major hotspots (with > 50 gully heads/km²) include the Chinese loess plateau, but also Iran, large parts of the Sahara Desert, the Andes and Madagascar. In addition, gully erosion also frequently occurs (with typical densities of 1-50 gully heads/km²) in the Mid-West USA, the African Rift, SE-Brazil, India, New-Zealand and Australia.

These regional patterns are mainly explained by topography and climate in interaction with vegetation cover. Overall, the highest gully densities occur in regions with some topography and a

(semi-)arid climate. Nonetheless, it is important to point out that not all gully heads are still actively retreating. Building on earlier insights into the magnitude and controlling factors of gully head retreat rates, we explore what our current results imply for assessing actual gully erosion rates at a global scale.