Geophysical Research Abstracts
Vol. 17, EGU2015-798-1, 2015
EGU General Assembly 2015

Quantifying gully erosion contribution from morphodynamic analysis of historical aerial photographs in a large catchment SW Spain

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Gully erosion is widely recognized as an important erosion process and source of sediment, especially in Mediterranean basins. Recent advances in monitoring techniques, such as ground-based LiDAR, drone-bounded cameras or photoreconstruction, allow quantifying gully erosion rates with unprecedented accuracy. However, many studies only focus on gully growth during a short period. In agricultural areas, farmers frequently erase gullies artificially. Over longer time scales, this results in an important dynamic of gully growth and infilling. Also, given the significant temporal variability of precipitation, land use and the proper gully erosion processes, gully growth is non-linear over time. This study therefore aims at analyzing gully morphodynamics over a long time scale (1957-2011) in a large catchment in order to quantify gully erosion processes and its contribution to overall sediment dynamics.

The 20 km2 study area is located in SW Spain. The extension of the gully network was digitized by photographic interpretation based on aerial photographs from 1957, 1981, 1985, 1999, 2002, 2005, 2007, 2009 and 2011. Gully width was measured at representative control points for each of these years. During this period, the dominant land use changed considerably from herbaceous crops to olive orchards. A field campaign was conducted in 2014 to measure current gully width and depth. Total gully volume and uncertainty was determined by Monte Carlo-based simulations of gully cross-sectional area for unmeasured sections.

The extension of the gully network both increased and decreased in the study period. Gully density varied between 1.93 km km-2 in 1957, with a minimum of 1.37 km km-2 in 1981 and a maximum of 5.40 km km-2 in 2011. Gully width estimated in selected points from the orthophotos range between 0.9 m and 59.2 m, and showed a good lognormal fit. Field campaigns results in a collection of cross-section measures with gullies widths between 1.87 and 28.5 m and depths from 0.55 m to 5.02 m. A gully width-depth relation was established according to a logarithm expression with an overall r2 of 0.82. As no historical information on gully depth was available, this relation was assumed to be constant over time.
Monte Carlo simulation was then used to generate width and depth values for the different gully segments, based on different lognormal distributions fitted to the estimated gully widths from 1957-2011 and on the width-depth regression. The calculated mean gully volume between 1953 and 2011 varied between 145.103 m3 and 2454.103 m3. The contribution of gully erosion to the overall sediment budget was found to be relatively stable between 1957-2008 with a mean value of 11.2 ton ha-1 year-1, while in the period 2008-2011 which includes frequent rainy days winter resulted in a mean value of 604 ton ha-1 year-1. Uncertainty estimates by Monte Carlo place the estimated contribution of gully erosion for this last period between 523-694 ton ha-1 year-1. The relation between gully erosion rates and driving factors such as land use change and rainfall was analysed in order to explain this variation. The high gully erosion rates of the period 2008-2011 could be linked to extreme rainfall events.

This study has determined gully erosion rates with a high temporal resolution over several decades. The results show that gully erosion rates are highly variable and therefore that a simple interpolation between the start and end date would highly underestimate gully contribution during certain years, such as for example between 2005-2011. Overall, gully erosion is shown to be an important process of sediment generation in Mediterranean basins.