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Short-term vs. medium-term monitoring for detecting gully-erosion variability in a Mediterranean environment: Addressing the time-scale problem in gully dynamics

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Gullies are amongst the most important sediment sources in small to medium-scale catchments and show highly distinctive spatio-temporal dynamics. This study investigates how medium-term gully-development data differ from short-term data, and which factors influence the spatial and temporal variability of gully development using 9 selected actively retreating bank gullies situated in Spanish basin landscapes (the Ebro, Guadalentín, Baza and Guadix Basins).

Small-format aerial photography using unmanned, remote-controlled platforms was taken at the gully sites in short-term intervals of usually 1 or 2 years over medium-term periods of 7-13 years between 1995 and 2009. This enabled to document the erosion processes at gully headcuts and sidewalls with the spatial and temporal resolutions corresponding to the process magnitude and frequency. Gully change during each monitoring period was determined using photogrammetry and GIS software, and various linear, areal and volumetric parameters of gully retreat were computed for each gully and monitoring period. Results show a high variability of annual gully retreat rates both between individual gullies and between observation periods. The mean linear headcut retreat rates range between 0.02 and 0.26 m a^{-1}. Gully area loss (approx. 0.8 to 22 m^2 a^{-1}) varies by a factor of 25 and gully volume loss (approx. 0.5 to 100 m^3 a^{-1}) by a factor of 200. For these, sidewall erosion may play a considerable part: for some gullies, the ratio of headcut to sidewall volume change is as low as 0.5.

A non-linear relationship between catchment area and medium-term gully headcut volume change was found for these gullies, confirming the result of earlier studies in the same region. The short-term gully volume changes observed at the individual gullies show very high variability: on average (median of all gullies), the maximum headcut change observed in 7-13 years was 14.3 times larger than the minimum change, but the degree of fluctuation varies strongly between the gullies. Not much difference in variability could be found for the headcut and sidewall parts of the gullies, although they clearly are subject to different erosion processes, and sidewall changes show no or much less dependency on precipitation than headcut retreat. The varying negative and positive influence of land-use and human activities – especially on connectivity of surface flow to the headcut – appears to play a dominant role in these study areas, both for short-term variability and medium-term difference in gully development.

The study proves the value of capturing spatially continuous, high-resolution 3D data using small-format aerial photography for detailed gully monitoring. Results confirm that short-term data are not representative for longer-term gully development and demonstrate the necessity of medium- to long-term monitoring. However, short-term data are still required to understand the processes causing fluctuations in gully erosion rates. In particular, human activity on varying time scales and its positive or negative effects on runoff production and connectivity need to be considered as an important factor for gully-erosion variability.