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Exploring frequency–size relationships of piping-related collapse sinkholes in different morphoclimatic environments

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Piping is a soil erosion process that occurs in almost all morphoclimatic zones and in a wide variety of sediment types. It plays a considerable role in badlands evolution. Pipes (subsurface tunnels) and the associated internal mechanical erosion transfer sediment from hillslopes to channels providing subsurface slope–channel connectivity. To the best of our knowledge, this process is not included in soil erosion models and it is not considered in sedimentary budget assessments. However, soil loss rates related to piping may reach significant values, ranging from below 1 t ha^{-1} y^{-1}, as reported in the US, to 33 t ha^{-1} y^{-1} in the Loess Plateau, China, and with a maximum of 550 t ha^{-1} y^{-1} in Spain. Therefore, there is a need to better understand this process.

This study explores the frequency-size distribution of pipe collapses (PCs) through the construction of empirical cumulative frequency curves. The analysis has been performed with field-based inventories of PCs from two different morphoclimatic environments: one area in the semi-arid Ebro Depression, NE Spain and 4 areas in the temperate Bieszczady Mts., SE Poland. This morphometric study allows us to check for the first time if frequency–size relationships of PCs follow a power-law as it is proven for many natural phenomena.

PCs developed when the upward propagation of cavity roofs by collapse processes (i.e., stoping) reached the surface, resulting in collapse sinkholes with vertical or nearly vertical walls. There was only subsurface connection between them and the associated gully/valley systems. These landforms are initiated by piping erosion and the foundering of the undermined pipe roofs. However, PCs may have a complex multi-episodic evolution. Once a PC is formed, it may change its size and geometry by mass-wasting processes acting on their walls and by coalescence with adjacent holes. In total, more than 720 PCs were analyzed (335 in Spain and 389 in Poland). The frequency–size relationships were based on the major axis (m) and area (m^2) of PCs.

The cumulative frequency curves of empirical data in the different areas show a similar pattern and high goodness of fit (R^2: 0.91-0.98). The cumulative frequency-size distribution follows a negative power-law for medium-size PCs. However, some differences can be noted. For instance, PCs in NE Spain show larger dimensions suggesting that mechanical factors such as the strength of the sediments play a decisive role, controlling the minimum size of the collapses (geomorphic threshold) and the frequency-size distribution of each area.

Exploring the magnitude-frequency relationships of PCs provides relevant information about the impact of piping on hillslope denudation and landscape evolution. It also offers critical quantitative data for subsidence hazard assessment.

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