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Gully erosion in the Caatinga biome, Brazil: measurement and stochastic modelling

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In contrast with inter-rill erosion, which takes a long time to modify the terrain form, gully erosion can fast and severely change the landscape. In the Brazilian semiarid region, a one-million km^2 area that coincides with the Caatinga biome, inter-rill erosion prevails due to the silty shallow soils. However, gully erosion does occur in the Caatinga, with temporal increasing severity. This source of sediment impacts the existing dense network of small dams, generating significant deleterious effects, such as water availability reduction in a drought-prone region. This study focuses on the Madalena basin (124 km^2, state of Ceará, Brazil), a land-reform settlement with 20 inhabitants per km^2, whose main economic activities are agriculture (especially Zea mays), livestock and fishing. In the catchment area, where there are 12 dams (with storage capacity ranging from 6.104 to 2.107 m^3), gully erosion has become an issue due to its increasing occurrence. Eight gully-erosion sites have been identified in the basin, but most of them have not yet reached great dimensions (depth and/or width), nor interacted with groundwater, being therefore classified as ephemeral gullies. We selected the three most relevant sites and measured the topography of the eroded channels, as well as the neighboring terrain relief, using accurate total stations and unmanned aerial vehicle. The data was processed with the help of software, such as DataGeosis (Office 7.5) and Surfer (11.0), providing information on gully erosion in terms of ($\mu \pm \sigma$): projection area (317$\pm$165 m^2), eroded mass (61$\pm$36 Mg) and volume (42$\pm$25 m^3), length (38$\pm$6 m), maximum depth (0.58$\pm$0.13 m) and maximum width (6.00$\pm$2.35 m). The measured data are then compared with those provided by the Foster and Lane model (1986). The model generated results with considerable scatter. This is possibly due to uncertainties in the field parameters, which are neglected in the deterministic approach of most physically-based models. We propose that the gully-erosion model approach consider the uncertainties of its main parameters/variables (e.g., soil density, soil grain-size distribution and peak discharge); and generate a histogram of responses, rather than a single deterministic value. The principle of maximum entropy should be used to derive the probability density functions of the uncertainty content of parameters and variables.