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Measurement and modeling of slope-wash and rill erosion on hillslopes using a novel combination of instrumented plots and remote sensing

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We have measured unit sediment fluxes and their relationship to unit water discharges over 7 orders of magnitude on hillslopes of up to 350 m in length in Arizona. Unit sediment and water fluxes were measured using a novel combination of instrumented monitoring plots and repeat photogrammetric surveys analyzed volumetrically. The monitoring plots, which are ideal for measuring sediment fluxes in relatively planar portions of the landscape dominated by slope-wash erosion, funnel water and sediment into a detention basin where bedload sediment fluxes are measured and then into a flume where water discharges and suspended sediment fluxes are measured at 1-minute intervals using a pressure transducer and calibrated turbidity sensor. Repeat photogrammetric surveys complement the monitoring plots by measuring sediment fluxes in rills that tend to form in areas of convergent flow during intense rain events. The volumetric change in each pixel is digitally routed to determine the volumetric sediment flux in each pixel associated with rilling during a rain event. Unit water discharges for every pixel cannot be measured directly but are estimated using a rainfall-runoff model calibrated to the monitoring plot data. The relationship between unit sediment fluxes and unit water discharges exhibits two piecewise power-function relationships with different exponents characterizing the slope-wash and rill-dominated regimes. We developed a novel landscape evolution model, inspired by the SIBERIA model but improved in specific ways optimized for hillslopes, that uses the measured piecewise power-function relationship between unit sediment fluxes and unit water discharges to predict hillslope evolution from time scales of individual events to decades. The predictions of the model are validated using ten years of observation of rill development at the study site. We provide equations for estimating the parameters of the piecewise power-function relationship for other hillslopes with different cover characteristics. This measurement and modeling framework must be tested at more study sites but is potentially useful for predicting the erosion of any hillslope, including alternative designs for landscape rehabilitations following mining or other anthropogenic disturbances.