The role of rainstorm properties on crop-land soil erosion: coupling event-scale modeling with a stochastic rainfall generator for estimating erosion risks

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Abstract

Soil erosion is a worldwide agricultural and environmental problem that threatens food security and ecosystem viability. In arable environments, the primary cause of soil loss is short and intense storms that are characterized with high spatiotemporal variability. The complex nature of these erosive events imposes a great challenge for erosion modeling and risk analysis. Accurate high-resolution measurement of rain intensity is often lacking or sparsely available. As a result, many studies rely on coarser-resolution rainfall data that often fail to address the impact of intra-storm properties. In this study, based on a novel statistical method, we quantify the discrete and cumulative multiannual impact of rainstorm regime on runoff and soil erosion to better understand the most important rainstorm properties on erosion rate and amount, and, to provide storm-scale risk analyses.

Central to our analyses is the coupling of a processes-based crop-land erosion model, Dynamic Water Erosion Prediction Project (DWEPP), with a stochastic rainfall generator that produces localized rainfall statistics at 5-min resolution (CoSMoS). To our knowledge, this is the first study that calibrated DWEPP runoff and sediment at the plot-scale on cropland. The model had an acceptable fit with measured event runoff and sediment data collected in northern Israel (NSE = 0.79 - 0.82). We then generated 300-year stochastic simulations of event-based runoff and sediment yield and used them to estimate erosion risk and calibrate a state-of-the-art frequency analysis method that explicitly accounts for rainstorms occurrence and properties. Results indicate that in the study area, high erosion rate events are characterized by intense rain bursts of short duration (shorter than the usually adopted erosivity index of 30-min), and not necessary by events of large volume accumulation or long duration. On these bases, we proposed an optimal rainfall erosivity index that combines intra-storm properties for the study area. As changes in rainstorm properties are expected under a changing climate, we expect our methodology to be a valuable tool for investigating the global concerns about future changes in soil erosion rate.