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The scale dependency of erosion and runoff for two agricultural catchments in the Western Paris Basin, France

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A major challenge in geomorphology is reconciling the disparity between runoff coefficients and erosion rates from the field to the catchment scale. In the European loess belt, a decrease of runoff coefficients and erosion rates occurs with increasing spatial scales. Indeed, it is important to understand the scale dependency of run-off and erosion to manage the off-site impacts of accelerated soil erosion. Accordingly, a continuous simulation of the scale dependency of runoff and erosion, from the field scale to the catchment scale (100 – 1000 km^2) was conducted with the Water and Sediment (WaterSed) model for two catchments (Andelle-756 km^2, and Austreberthe-214 km^2) over 12 years (>1000 events). Scale effects were evident with a 100-fold decrease in runoff coefficients and sediment delivery ratios between the field scale and the catchment scale. In spite of a low variability of the annual rainfall (19%), the inter-annual variability of the runoff volume (37%) and erosion rates (92%) at catchment outlets were high. The inter-annual variability of runoff and erosion was closely linked to the number of extreme events per year and their distribution through the year, in particular during periods with highly crusted soil surface states. For these high magnitude events, a complex distributed modelling approach was not necessary as the ability of the soil surface and of the landscape to retain overland flows are largely exceeded. The seasonality of soil surface characteristics also affected the scale dependency of runoff and erosion, from the field scale to the catchment scale. However, this is only observed up to a certain spatial extent, i.e. where hillslope erosion processes are governed by hortonian overland flow. When saturation flows are generated, topography and soil depth become the dominant factors. Understanding runoff and sediment response at different scales should focus on the location and amount of runoff and sediment production within the catchment and the capacity of the downstream flow path to retain or transfer overland flow and sediment. Furthermore, this study demonstrates the need to implement model that represent both hortonian and saturation flows when simulating erosion events at the catchment scale.