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Assessing temporal variations in connectivity through suspended sediment hysteresis analysis

Sophie Sherriff (1,2), John Rowan (2), Owen Fenton (1), Phil Jordan (3), Alice Melland (4), Per-Erik Mellander (5), and Daire Ó hUallacháin (1)

(1) Teagasc, Crops Environment and Land Use Programme, Wexford, Ireland, (2) Geography, School of Social Sciences, University of Dundee, Dundee, DD1 4HN, UK, (3) School of Environmental Sciences, Ulster University, Coleraine, Co. Derry, UK, (4) University of Southern Queensland, Toowoomba, Australia, (5) Agricultural Catchments Programme, Teagasc, Wexford, Ireland

Connectivity provides a valuable concept for understanding catchment-scale sediment dynamics. In intensive agricultural catchments, land management through tillage, high livestock densities and extensive land drainage practices significantly change hydromorphological behaviour and alter sediment supply and downstream delivery. Analysis of suspended sediment-discharge hysteresis has offered insights into sediment dynamics but typically on a limited selection of events. Greater availability of continuous high-resolution discharge and turbidity data and qualitative hysteresis metrics enables assessment of sediment dynamics during more events and over time. This paper assesses the utility of this approach to explore seasonal variations in connectivity.

Data were collected from three small (c. 10 km^2) intensive agricultural catchments in Ireland with contrasting morphologies, soil types, land use patterns and management practices, and are broadly defined as low-permeability supporting grassland, moderate-permeability supporting arable and high-permeability supporting arable. Suspended sediment concentration (using calibrated turbidity measurements) and discharge data were collected at 10-min resolution from each catchment outlet and precipitation data were collected from a weather station within each catchment. Event databases (67-90 events per catchment) collated information on sediment export metrics, hysteresis category (e.g., clockwise, anti-clockwise, no hysteresis), numeric hysteresis index, and potential hydrometeorological controls on sediment transport including precipitation amount, duration, intensity, stream flow and antecedent soil moisture and rainfall. Statistical analysis of potential controls on sediment export was undertaken using Pearson's correlation coefficient on separate hysteresis categories in each catchment. Sediment hysteresis fluctuations through time were subsequently assessed using the hysteresis index.

Results showed the numeric hysteresis index varied over time in all three catchments. The exact response was catchment specific reflecting changing sediment availability and connectivity through time as indicated by dominant controls. In the low-permeability grassland catchment, proximal sources dominated which was consistent with observations of active channel bank erosion. Seasonal increases in rainfall increased the erosion potential but continuous grassland cover mitigated against hillslope sediment contributions despite high hydrological connectivity and surface pathways. The moderate-permeability arable catchment was dominated by events with a distal source component but those with both proximal and distal sediment sources yielded the highest sediment quantities. These events were driven by rainfall parameters suggesting sediment were surface derived and the hillslope was hydrologically connected during most events. Through time, a sustained period of rainfall increased the magnitude of negative hysteresis, likely demonstrating increasing surface hydrological connectivity due to increased groundwater saturation. Where increased hydrological connectivity coincided with low groundcover, the largest sediment exports were recorded. Events in the high permeability catchment indicated predominantly proximal sediments despite abundant distal sources from tilled fields. The infiltration dominated high permeability soils hydrologically disconnected these field sources and limited sediment supply. However, the greatest sediment export occurred in this catchment suggesting thresholds existed, which when exceeded during higher magnitude events, resulted in efficient conveyance of sediments. Hysteresis analysis offers wider utility as a tool to understand sediment pathways and connectivity issues with applications to catchment management strategies.