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Best Water Related Presentation at Environ 2026: Prosper Kpiebaya (Doctoral student in Biosystems and Food Engineering, Department of Biosystems and Food Engineering, University College Dublin)

“Erosion-driven soil carbon dynamics in a headwater agricultural catchment dominated by microtopography”

Soil erosion processes impact soil organic carbon (SOC) dynamics, which directly affect soil health, agricultural productivity, and climate change mitigation. Globally, SOC displaced as a result of soil erosion is estimated to be between 4 and 6 Pg C yr⁻¹, highlighting the urgent need for a more comprehensive understanding of these dynamics (Lal, 2003, 2005). Understanding soil erosion and SOC redistribution is critical for sustainable land management and water-quality protection.

In agricultural landscapes, erosion does not necessarily result in net export; rather, sediment and associated carbon may be redistributed internally, leading to spatial heterogeneity in both soil loss and carbon storage. While empirical or score-based approaches identify vulnerable areas, they often lack the mechanistic capacity to resolve interactions among topography, kinetic energy, and detachment processes.

The present study employed the Morgan-Morgan-Finney (MMF) erosion model coupled with high-resolution LiDAR-derived topography, spatial soil parameters, and land-use data to simulate the erosion rates in the catchment. Outputs from the model included kinetic energy, raindrop detachment, moisture storage capacity, runoff detachment, transport capacity, and soil loss. Eroded SOC was derived by coupling modelled sediment fluxes with spatial SOC to identify hotspots of eroded and deposited SOC.

Results indicate a catchment dominated by internal sediment redistribution rather than net export. Spatially, erosion clusters align with steep gradients and elevated runoff zones, whereas deposition concentrates in flatter concave positions and footslopes where transport capacity declines. Model diagnostics show widespread raindrop detachment driven by high kinetic energy, but localized runoff detachment governs erosion hotspots. Frequent exceedance of transport capacity promotes rapid downslope settling, indicating a transport-limited system with strong in-field storage.

SOC patterns mirror sediment redistribution suggesting that SOC mobilisation is function of erosion. Catchment-scale estimates indicate that a substantial proportion of mobilised carbon is exported via hydrological pathways. Hotspots of labile carbon loss are concentrated in areas that overlap with high erosion intensity, indicating preferential mobilisation of the most reactive and biologically available carbon fractions (Lal, 2005, 2019). Because labile carbon responds rapidly to disturbance, its loss represents a disproportionate impact on soil fertility and short-term carbon cycling, with implications for downstream carbon fluxes and greenhouse gas emissions. Spatial analysis shows that labile C export is strongly associated with hydrologically sensitive areas and

connected slope positions. These findings demonstrate that microtopography and hydrological connectivity exert first-order controls on both sediment and carbon fluxes, even under relatively low erosion rates typical of grassland systems.



Figure 1: Erosion (left) and Deposition (right) in the catchment

Overall, these insights not only inform current land management and climate mitigation policies but also provide a scientific basis for more targeted, catchment-specific interventions aimed at reducing erosion-driven carbon losses, protecting water quality, and sustaining soil fertility in agricultural landscapes.