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A critical source area phosphorus index with topographic transport factors using high resolution LiDAR digital elevation models

Ian Thomas (1,2), Paul Murphy (3), Owen Fenton (4), Oliver Shine (1), Per-Erik Mellander (1), Paul Dunlop (2), Phil Jordan (1,2)

(1) Agricultural Catchments Programme, Teagasc, Johnstown Castle, Wexford, Co. Wexford, Ireland, (2) School of Environmental Sciences, University of Ulster, Coleraine, Northern Ireland, UK, (3) Environment and Sustainable Resource Management Section, School of Agriculture and Food Science, University College Dublin, Dublin 4, Ireland, (4) Teagasc, Johnstown Castle, Wexford, Co. Wexford, Ireland

A new phosphorus index (PI) tool is presented which aims to improve the identification of critical source areas (CSAs) of phosphorus (P) losses from agricultural land to surface waters. In a novel approach, the PI incorporates topographic indices rather than watercourse proximity as proxies for runoff risk, to account for the dominant control of topography on runoff-generating areas and P transport pathways. Runoff propensity and hydrological connectivity are modelled using the Topographic Wetness Index (TWI) and Network Index (NI) respectively, utilising high resolution digital elevation models (DEMs) derived from Light Detection and Ranging (LiDAR) to capture the influence of micro-topographic features on runoff pathways. Additionally, the PI attempts to improve risk estimates of particulate P losses by incorporating an erosion factor that accounts for fine-scale topographic variability within fields. Erosion risk is modelled using the Unit Stream Power Erosion Deposition (USPED) model, which integrates DEM-derived upslope contributing area and Universal Soil Loss Equation (USLE) factors. The PI was developed using field, sub-field and sub-catchment scale datasets of P source, mobilisation and transport factors, for four intensive agricultural catchments in Ireland representing different agri-environmental conditions. Datasets included soil test P concentrations, degree of P saturation, soil attributes, land use, artificial subsurface drainage locations, and 2 m resolution LiDAR DEMs resampled from 0.25 m resolution data. All factor datasets were integrated within a Geographical Information System (GIS) and rasterised to 2 m resolution. For each factor, values were categorised and assigned relative risk scores which ranked P loss potential. Total risk scores were calculated for each grid cell using a component formulation, which summed the products of weighted factor risk scores for runoff and erosion pathways. Results showed that the new PI was able to predict in-field risk variability and hence was able to identify CSAs at the sub-field scale. PI risk estimates and component scores were analysed at catchment and subcatchment scales, and validated using measured dissolved, particulate and total P losses at subcatchment snapshot sites and gauging stations at catchment outlets. The new PI provides CSA delineations at higher precision compared to conventional PIs, and more robust P transport risk estimates. The tool can be used to target cost-effective mitigation measures for P management within single farm units and wider catchments.