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Modelling of phosphorus pollution risk to watercourses in Scotland using Bayesian Belief Networks

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Phosphorus (P) pollution is a major cause of surface water quality failures in Scotland. Process-based, integrated catchment models are often used to formalise current knowledge of a catchment system and to help understand the links between P inputs and water quality. However, process-based modelling is often hampered by lack of available data to allow plausible representation of the complex processes and interactions involved in P mobilisation, transport and delivery to receiving waters, as well as by the gaps in the understanding of the ecological impacts. Here we develop a risk-based model based on Bayesian belief networks (BBNs) to facilitate the understanding of the effects of land use on P pollution risk within an uncertainty framework at a Scotland-wide scale. BBNs are ideally suited to deliver such national-scale understanding, as they allow the integration of both quantitative and qualitative information from a range of sources (including data, other model outputs and non-scientific knowledge, such as expert opinion) in one model, whilst making explicit the uncertainties associated with both the model and data.

From an early stage, the perceptual model in this study has been developed in close collaboration with disciplinary experts covering the areas of hydrology, biogeochemistry, soil science and environmental modelling, as well as direct inputs from the regulator Scottish Environmental Protection Agency. Firstly, the modelling objectives and software requirements were determined in a meeting with the regulator, followed by 1:1 consultations with disciplinary experts. Secondly, disciplinary experts were brought together in an interactive workshop to discuss the model structure, followed by another meeting with the stakeholders. The BBN is presented as a clear visual spatial network, covering the nutrient 'source-mobilisation-transport-impact' continuum, ideally suited for stakeholder engagement in both model development and application.

Following the agreement on the perceptual model structure, the BBN node states and probabilities will be derived from available data and from structured stakeholder input using the SHELF elicitation framework. We use existing spatiotemporal data, including hydrometeorological variables (rainfall and runoff, overland and subsurface flow), soil properties (hydrological response - Hydrology Of Soil Types, degree of P saturation, compaction, drainage, erosion risk and rates), landscape characteristics (connectivity, land use, management) and point source effluent loads (septic tanks and sewage treatment plants). An initial procedural model is currently being built for a test catchment in E Scotland (Lunan), before Scotland-wide up-scaling.

The presented modelling approach will facilitate the co-construction of the research outcomes by the academic and the stakeholder communities, thus building on all available data and knowledge to promote the application of this decision support tool in river catchment management. The modelled scenarios will inform the implementation of water quality mitigation measures, while the quantified model uncertainties will help to inform further research, data collection and process-based modelling.