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A systems approach to modelling phosphorus pollution risk in Scottish rivers using Bayesian Belief Networks

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Water pollution is an important reason for the failure of 17 % of Scottish waterbodies to reach Good Ecological Status under the Water Framework Directive (WFD). Among the multiple pressures affecting water quality, phosphorus (P) pollution is a major cause of surface water quality failures. Reducing the P pollution in agricultural catchments requires evidence-based decision-making about the effectiveness of land management mitigation measures and their spatial targeting, under current conditions and future scenarios.

Here we introduce a decision-support tool, *PhosphoRisk*, that uses a Bayesian Belief Network to integrate information on the potential effects of water quality mitigation measures, including data and expert opinion, and parameterizations of the uncertainties in these quantities, in a single model. Specifically, the model integrates spatially distributed geographic information system data about land use and crops, soil erosion risk, topographic connectivity, presence of soil drains, soil hydrological leaching and P binding properties, farm yard locations for incidental P losses, sewage treatment works and septic tank location, with catchment rainfall and runoff data, fertiliser application rates and likely buffer effectiveness. Critical source areas of diffuse and point source pollution risk are mapped on 100x100 m raster grids for two pilot catchments in north-east Scotland – Lunan Water (124 km^2) and Tarland (72 km^2). The model simulates the probability of P concentration falling into the WFD high-good-moderate-poor classification categories at the catchment outlet and models P source apportionment alongside the effectiveness of mitigation measures such as buffer strips and fertiliser application rates.

Sensitivity analysis of the model reveals the importance of hydrology for the seasonal dilution of P concentrations at the catchment outlet. Diffuse point sources, such as incidental losses from farmyards, are also important for this model of P pollution risk, along with sewage treatment works. The presence/absence of soil drains and septic tanks have a smaller influence on the outputs from the model.

The *PhosphoRisk* decision support tool facilitates system-level thinking about phosphorus pollution and brings together academic and stakeholder communities to co-construct a model structure appropriate to the region it is modelling. The model reveals the causal relationships between the modelled factors driving an understanding of the effects of land use on P pollution risk in Scottish catchments. The modelled scenarios will help to inform and target water quality mitigation measures in high risk areas, while the quantified model uncertainties will inform further research and motivate targeted data collection.