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A probabilistic decision support tool for field level pesticide risk assessment in a small drinking water catchment on the Island of Jersey

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Pesticides are contaminants of priority concern regulated under the EU Water Framework Directive 2000 (WFD) and its daughter Directives. Article 7 of the WFD promotes a 'prevention-led' approach that prioritises pollution prevention at source rather than costly drinking water treatment.

However, the effectiveness of pollution mitigation measures in catchment systems is uncertain and catchment management needs to consider local biophysical, agronomic, and social aspects. Local risk assessment and management of water contamination in drinking water catchments informed by process-based models is costly and often hindered by lack of data. Therefore, spatial risk indices have been developed to evaluate the intrinsic risk from pesticide pollution. However, these risk assessment approaches do not explicitly account for uncertainties in complex processes and their interactions.

In this study, we developed a probabilistic decision support tool (DST) based on spatial Bayesian Belief Networks (BBN) to inform field-level pesticide mitigation strategies in a small drinking water catchment (3.5 km^2) with limited observational data. The DST accounts for the spatial heterogeneity of soil properties, topographic connectivity, and agronomic practices; temporal variability of climatic and hydrological processes as well as uncertainties related to pesticide properties and the effectiveness of management interventions. Furthermore, the graphical nature of the BBN facilitated interactive model development and evaluation with stakeholders, while the ability to integrate diverse data sources allowed an effective use of available data.

The risk of pesticide loss via two pathways (overland flow and leaching to groundwater) was simulated for five active ingredients. Risk factors included climate and hydrology (temperature, rainfall, evapotranspiration, overland and subsurface flow), soil properties (texture, organic matter content, hydrological properties), topography (slope, distance to surface water/depth to groundwater), landcover and agronomic practices, pesticide properties and usage. The effectiveness of mitigation measures such as delayed pesticide application timing; 10%, 25% and 50% application rate reduction; field buffers; and presence/absence of soil pan on risk reduction were evaluated.

Sensitivity analysis identified the application rates, rainfall, and overland flow connectivity as the most important risk factors. Pesticide pollution risk from surface water runoff showed clear spatial variability across the study catchment, while groundwater leaching risk was more uniform. Combined interventions of 50% reduced pesticide application rate, management of plough pan, delayed application timing and field buffer installation reduced the probability of high-risk from overland flow in several fields.

The DST provided a probabilistic dynamic field-scale assessment of 'critical risk areas' of pesticide pollution in time and space and is easily transferable to neighbouring catchments.