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A Monte Carlo approach to the inverse problem of diffuse pollution risk in agricultural catchments

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The hydrological and biogeochemical processes that operate in catchments influence the ecological quality of freshwater systems through delivery of fine sediment, nutrients and organic matter. As an alternative to the, often complex, reductionist models we outline a – data-driven – approach based on 'inverse modelling'. We invert SCIMAP, a parsimonious risk based model that has an explicit treatment of hydrological connectivity, and use a Bayesian approach to determine the risk that must be assigned to different land uses in a catchment in order to explain the spatial patterns of measured in-stream nutrient concentrations. First, we apply the model to a set of eleven UK catchments to show that: 1) some land use generates a consistently high or low risk of diffuse nitrate (N) and Phosphate (P) pollution; but 2) the risks associated with different land uses vary both between catchments and between P and N delivery; and 3) that the dominant sources of P and N risk in the catchment are often a function of the spatial configuration of land uses. These results suggest that on a case by case basis, inverse modelling may be used to help prioritise the focus of interventions to reduce diffuse pollution risk for freshwater ecosystems. However, a key uncertainty in this approach is the extent to which it can recover the 'true' risks associated with a land cover given error in both the input parameters and equifinality in model outcomes. We test this using a set of synthetic scenarios in which the true risks can be pre-assigned then compared with those recovered from the inverse model. We use these scenarios to identify the number of simulations and observations required to optimize recovery of the true weights, then explore the conditions under which the inverse model becomes equifinal (hampering recovery of the true weights) We find that this is strongly dependent on the covariance in land covers between subcatchments, introducing the possibility that instream sampling could be designed or subsampled to maximize identifiability of the risks associated with a given land cover.