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Linking climate and land-use scenarios to ecological status of lakes: a Bayesian network approach

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The European Water Framework Directive (WFD) requires that the quality of surface waters is assessed by ecological status, which is based primarily on biological indicators such as phyoplankton abundance and community composition in lakes. Prediction of water quality under future climate or management scenarios should therefore include such regulatory assessment endpoints. However, process-based water quality models typically predict only abiotic variables such as nutrient concentrations. Moreover, biological monitoring data are typically more costly and therefore have lower frequency than abiotic data. A common problem in water quality assessment and prediction is therefore the linking of process-based catchment and lake models to biological assessment endpoints. We have used a Bayesian network (BN) approach to address this problem and to bridge the gap between process-based models and classification systems for water quality. Our case study is the eutrophicated Lake Vansjø with its catchment Morsa in South-Eastern Norway. The lake has suffered from blooms of toxic cyanobacteria, which benefit from high nutrient input as well from warm and stable weather conditions. A BN model was developed as a meta-model to link the key input and output variables from the following components: future climate and land-use scenarios (from the past EU project MARS); a hydrological model (Persist); a catchment model (INCA-P); a lake model (MyLake); biological monitoring data (cyanobacteria and other phytoplankton); and the Norwegian classification system for lake quality. With the BN approach, variables from all data sources could be linked in a common format (discrete probability distributions). To quantify the links (as conditional probability tables), we used different options depending on the data availability: frequency distributions, regression models and/or expert knowledge. With the final BN model, we could predict the probability of achieving the WFD management target (good ecological status) under different climate and land-use scenarios and for different time horizons (2030, 2060).
The inclusion of cyanobacteria in this model consistently resulted in worse status assessments, compared to the predictions from the process-based models without this biological indicator. This demonstrates a strength of the BN approach: the inclusion of biotic indicators in water quality modelling will result in a more correct assessment, which can result in better protection of the water resource. Our future directions include: (1) better validation of the model; (2) better methods for quantification of conditional probability tables in cases with insufficient data; and (3) adapting the model for seasonal weather forecasting (in the on-going European project WateXr).