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The need for Bayesian approaches in water research and management

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The goal of environmental managers and politicians is (or should be) to take decisions that result in an ideal trade-off between costs and societal benefits. Technically, this can be done by eliciting societal preferences (by surveys, stakeholder involvement processes, public votes, etc.) and choosing the decision alternative that leads to the best fulfillment of these objectives. Even if the preferences are known, this decision making process is difficult, as the outcomes of decision alternatives in environmental management are often very uncertain. The support of environmental management thus requires the quantification of the current scientific knowledge about the outcomes of decision alternatives and their uncertainty. This can best be done by inter-subjective degrees of belief quantified with (Bayesian) probabilities[1].

The Bayesian approach to the description of knowledge provides us with a consistent methodology for incremental learning (the final result is independent on the partitioning of new information). It can be applied to describe subjective beliefs, e.g. elicited from a farmer about her reaction to a fertilizer tax, or intersubjective beliefs as it is needed to describe the current state of knowledge of the scientific community. Intersubjective beliefs are either jointly elicited from multiple experts or combined from individual expert statements. The use of intersubjective beliefs is in accordance with scientific quality control procedures, such as peer review[1]. Very poor knowledge can be considered by imprecise probabilities[2].

The conceptual need for a Bayesian approach is in high synergy with many practical aspects that are much easier to handle in a Bayesian than in a frequentist context. Among these are the explicit and documented use of prior information, dealing with multi-objective calibration[3], inference of parameters of stochastic models[4,5], Bayesian model averaging, the formulation and updating of expert-based probability network models. The disadvantage of high computational requirements for Bayesian inference becomes less relevant with improvements of algorithms and high performance computation.

In my view, more emphasis is needed on using stochastic models. While deterministic models can represent an empirical description of the mean behavior of a stochastic model, explicit modelling of intrinsic or externally induced stochasticity can better represent unknown or fluctuating external influences, intrinsic stochasticity, and model structural error. Some examples from hydrological, water quality and ecological modelling will be used to illustrate the concepts.

Some references from our work; many external references are cited therein:

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