Water Quality Trading: How to Deal with Uncertainties in Modeling Nonpoint Sources?

Ali Tasdighi[a], Mazdak Arabi[a] and Marzieh Motallebi[b]
[a] Department of Civil and Environmental Engineering, Colorado State University
[b] Forestry and Environmental Conservation Department, Clemson University

Abstract. Quantifying the nonpoint source pollutant loads and assessing the water quality benefits of conservation practices (BMPs) are prone to different types of uncertainties which have to be taken into account when developing nutrient trading programs. Although various types of modeling uncertainties (parameter, input and structure) have been examined in the literature more or less, the impact of modeling uncertainties on evaluation of BMPs has not been addressed sufficiently. Of rare cases where impacts of modeling uncertainties on BMPs are studied, all have assessed the impact of only one type of uncertainty. This is while the absence of involving one or more sources of uncertainty may lead to an incorrect conclusion about the sources of the errors. Currently, "trading ratios" are used within nutrient trading programs to account for variability of nonpoint source loads and effectiveness of BMPs. However, we were not able to find any case of some rigorous scientific approach to account for any type of uncertainties in trading ratios. In this study, Bayesian inferences were applied to incorporate input, parameter and structural uncertainties using a statistically valid likelihood function. IPEAT (Integrated Parameter Estimation and Uncertainty Analysis Tool), a framework developed for simultaneous evaluation of parameterization, input data, model structure, and calibration/validation data uncertainty and their contribution to predictive uncertainty was used to quantify the uncertainties in effectiveness of agricultural BMPs while propagating different sources of uncertainty. SWAT was used as the simulation model. SWAT parameterization was done for three different model structures (SCS CN I, SCS CN II and G&A methods) using a Bayesian based Markov Chain Monte Carlo (MCMC) method named Differential Evolution Adaptive Metropolis (DREAM). For each model structure, the Integrated Bayesian Uncertainty Estimator (IBUNE) was employed to generate latent variables from input data. Bayesian Model Averaging (BMA) was then used to combine the models and Expectation-Maximization (EM) optimization technique was used to estimate the BMA weights. Using this framework, the impact of different sources of uncertainty on effectiveness of BMPs was assessed and bands of uncertainty around BMP efficiencies were determined. Also, using the predicted cumulative distribution functions (CDFs) for nonpoint loads (Agriculture) and CDFs of observed loads for point sources (WWTPs), trading ratios for specific trades were determined under uncertainty.