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Empirical Relationship Between Sensitivity Index and Mean Square Error of Prediction: a case study for greenhouse gas emission

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Abstract

Sensitivity analysis is frequently used to select the most influent parameters to be estimated from scarce available data. However, the capability of this approach to improve model predictions is not well known, especially for complex environmental models. This paper investigates the relevance of estimating the most influent parameters only and setting the other parameters to their nominal values. More precisely, an empirical relationship is established between the global sensitivity index of a parameter and the Mean Square Error of Prediction, for a dynamic model simulating greenhouse gas emission. The results show that the estimation of parameters with low sensitivity indices is likely to give poor model predictions whereas the estimation of the parameters with high indices leads systematically to a reduction of the mean square error of prediction.

Keywords**:** Dynamic model, Multivariate Sensitivity Analysis, Mean Square Error of Prediction

1. Main text

Dynamic models are frequently used in ecology, agronomy, risk assessment and environmental sciences for simulating crop, environmental variables and risk targets of interest at a discrete time step. These models are useful for pest management, for greenhouse gas management, for microbiological risk assessment. For instance, CERES-EGC is a discrete-time model that simulates the emission of nitrous oxide (N_2O), a potent greenhouse gas, into the atmosphere on a daily time step (Gabrielle *et al.*, 2006). Discrete-time models can include many parameters whose values are uncertain. The uncertainty on the parameters is a major source of uncertainty on the model predictions. Consequently, the estimation of the uncertain parameters from experimental data is an important step and model performances depend for a large part on the accuracy of the parameter estimates (Butterbach-Bach *et al.*, 2004). Model predictions based on inaccurate parameter values are unreliable and hardly meaningful.

In general, it is impossible to estimate all parameters of complex models simultaneously (Bechini *et al.*, 2005). A common strategy consists in selecting a subset of parameters to be calibrated using sensitivity analysis, and fixing the others to some nominal values (Wallach *et al.*, 2001; Makowski *et al.*, 2006). Global sensitivity analysis for

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models with one output variable (Saltelli *et al.*, 2008) and Multivariate sensitivity analysis for dynamic models (Lamboni *et al.*, 2009) allow modellers to perform factor prioritization, i.e to determine which subset of parameters accounts for most of the output uncertainty.

Using sensitivity analysis to select the parameters to be estimated relies mainly on the intuitive idea that predictions are more accurate when the parameters with the greatest influence are estimated accurately. However, the sensitivity indices are based solely on model simulations whereas model quality is measured by using actual data. In this paper, we develop an empirical relationship between parameter sensitivity indices and a model quality measure: Mean Square Error of Prediction (MSEP). More precisely, this paper aims to quantify how parameter selection based on multivariate sensitivity analysis can improve the CERES-EGC predictions. The CERES-EGC model evaluation is done with measurements collected in several experimental plots. The results in Figure 1 show that the estimation of the parameters with the highest multivariate sensitivity indices lead to a reduction of the prediction errors of the model CERES-EGC, essentially by avoiding worst-case parameter selections.

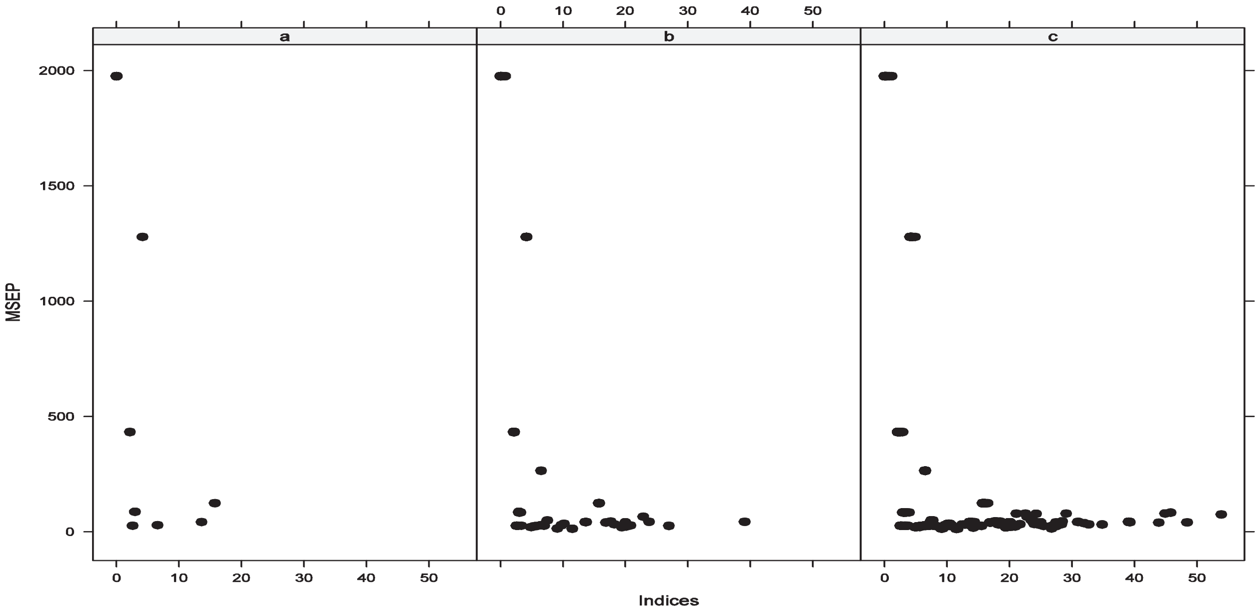

Figure 1: Empirical relation between MSEP and multivariate sensitivity index (GSI) when estimating one parameter (a); two parameters (b) and three parameters (c) of CERES-EGC model.

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