Pesticide leaching under climate change: the role of climate input uncertainty

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Introduction

Climate change influences the risk of pesticide leaching to surface and ground waters in different ways, since higher temperatures and increased rainfall lead to contrasting effects on pesticide leaching. To assess the composite impact of these adverse effects process-oriented modelling is required, which includes a number of different types of uncertainty. Steffens et al. (2013) compared the role of model structural error with parameter uncertainty for the pesticide fate model MACRO, but only included one climate scenario. The aim of this study was to assess the role of climate input uncertainty in long-term predictions of pesticide leaching under climate change and more specifically to explore if: (1) input from different climate scenarios result in similar changes of predicted future pesticide losses and (2) climate input uncertainty has a larger impact on the predictions of pesticide loss relative to the parameter uncertainty of the pesticide fate model. To address these issues, 30-year simulations of pesticide leaching under present and future climate conditions were performed with the pesticide fate model MACRO5.2 (Larsbo et al., 2005). We calibrated the model against comprehensive field data from a well-structured clay soil under long-term no-tillage practice in south-west Sweden (Lanna) with a GLUE-type approach and identified 56 acceptable parameterizations that described the observations equally well. A nine-member ensemble of regional climate scenarios covering different global circulation models (GCM’s), greenhouse gas emission scenarios and initial conditions of the GCM’s (Kjellström et al., 2011) was used to represent the uncertainty in future climate projections.

The effects on leaching might strongly depend on pesticide properties and application timing. We, therefore, explored six different pesticide application scenarios combining three different hypothetical compounds and two application seasons (spring and autumn) with an annual application of 0.45 kg/ha on a drained clay soil cropped with winter wheat. The hypothetical compounds were generated by multiplying the calibrated sorption coefficients (Koc-values) for bentazone with a value of 1, 10 and 50 to represent weakly, moderately and strongly sorbed pesticides, respectively. As a target output, we focused on the accumulated losses to tile drains over the 30-year period expressed as percentage of the applied dose.

Results & Discussion

Simulated pesticide leaching was highest for weakly, followed by moderately and strongly sorbed compounds and generally higher after autumn application than after spring application under both present and future climate conditions. The simulated pesticide losses are shown for the weakly sorbed pesticide applied in spring in Fig. 1a. Figure 1b shows the results for the changes in pesticide leaching from present to future. Both the magnitude and the direction of predicted change in pesticide leaching from present to future depended strongly on the particular climate scenario. The change in pesticide leaching varied between -5 and +8% of the applied dose, accounting for the response in pesticide leaching to the whole ensemble of climate scenarios. Thus, no consistent direction of change was predicted. The aggregated ensemble predictions based on both acceptable parameterizations and different climate scenarios could, however, provide robust probabilistic estimates of future pesticide losses and assessments of changes in pesticide leaching risks. For example, the ensemble prediction in Fig.1b shows a probability of 70% that the risk for pesticide leaching will not increase in a future climate, but rather will decrease or stay unchanged.
Fig. 1: Cumulative distribution functions of the weakly sorbed pesticide applied in spring for (a) absolute pesticide leaching losses and (b) changes in predicted pesticide leaching losses from present to future. The grey lines denote the results for the different climate scenarios and the black-white dashed line the ensemble prediction of the climate scenario ensemble, the black solid line denotes the present climate (in a) and the thin dashed black line the “zero-change” (in b).

Parameter uncertainty was the dominating source of uncertainty in predicting actual pesticide losses under present and future climate conditions (Fig. 1a), contributing 85-98% to the total uncertainty. For predicting the changes from present to future, however, the role of parameter uncertainty was reduced to 35-70% of the total uncertainty, because the different parameterizations of the MACRO-model responded consistently and similarly to changes in climate (cf. steep slopes in Fig. 1b). These results are underlined by the fact that the mean predictions of the climate ensemble for the different parameterizations were significantly different for all pesticide application scenarios when predicting actual losses, but did not differ significantly for the weakly sorbed pesticide or any spring-applied compound, when predicting changes in leaching losses.

Conclusions
From this study, we conclude that (i) climate input uncertainty is important and should be accounted for by applying an ensemble of possible climate scenarios; (ii) a deterministic approach based on one acceptable parameterization of the impact model seems sufficient if the focus of the analysis is on assessing average changes in pesticide leaching between present and future, at least for many scenarios of interest (mobile or spring applied compounds); (iii) for probabilistic assessments of changes in pesticide leaching, as much information as possible should be included in the analysis, i.e. ensembles of both parameter sets and climate scenarios. This would increase the robustness of the results and confidence in predictions of directions and trends.

References