Sensitivity analysis and metamodeling methods for designing buffer strips to protect water from pesticide transfers.

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In France, significant amounts of pollutants are measured in surface water, partly due to the use of pesticides by agriculture. In order to decrease this contamination, reasoning pesticides applications at field and taking into account the rainfall forecasting are recommended in addition to more global management practices at the watershed scale. Among these, buffer zones are landscape elements that are either maintained or intentionally set up to ensure the interception and the mitigation of contaminant transfers arising from fields towards aquatic environments. Among buffer zones, Vegetative Filter Strips (VFS, such as grassed or wooded strips) can be useful tools to help achieving the "good ecological status" of the European Water Framewok Directive in watersheds. They are now mandatory along rivers in more and more countries, due to their recognized effectiveness to limit pesticide and sediment transfer by surface runoff (Asmussen et al., 1977; Dosskey, 2001). However, the general effectiveness of edge-of-field buffer strips to reduce runoff transport of pesticides can highly depend on many conditions of implementation and maintenance. It particularly requires an optimal design (position in the hillslope and size) which depends on the agronomic conditions, the studied hillslope's soil characteristics and the climate.

In this context, Irstea developed a methodology which allows designing site-specific VFS by simulating their efficiency to limit transfers among a hillslope (Carluer et al., 2014). The modeling toolkit consists in several steps like analyzing the watershed and its characteristics (soil, climate, cultural practices), and running dynamical models, in particular the mechanistic model VFSMOD (Munoz-Carpena et al., 1999). At the end this toolkit delivers the optimal VFS width considering the needed filter efficiency (for example, 70% of runoff reduction). This very complete method assumes that the user provides detailed field knowledge and data (type of soil of the contributive area and of the VFS, rainfall rate, water table depth, slope, etc.), which are not easily available in many practical applications. Moreover, the variety of tools, which rely on several interfaces or several programming languages makes it relatively difficult to take over the design procedure.

In order to fill in the lack of real data in many practical applications, a first study was conducted on a set of virtual scenarios, among which the user would choose the most relevant one considering its own situation. They were selected by expertise to encompass a large range of agro-pedo-climatic conditions in Europe, describing both the upslope agricultural field and the VFS characteristics. The sizing method was applied on all these scenarios, and a Global

Sensitivity Analysis (GSA, Sobol method) of the VFS optimal length was performed to understand the influence of parameters and their interactions, and identify priorities for data collecting and management. The GSA applied in a specific watershed of North-West of France (Lauvernet et al 2015) showed that the optimal VFS width is very sensitive to i) the Curve Number (an empirical parameter describing the potential surface runoff generation of the contributive area, USDA-SCS, 1972), ii) the saturated hydraulic conductivity of the VFS soil and iii) the water table depth. These parameters, which particularly depend on local conditions, must then be defined as accurately as possible. The performed sensitivity analysis procedure provided interesting results, but these are valid only under these climatic conditions and in this specific watershed. Yet the study was based on a design of experiments defined on the field expertise and finally led to a full factorial design. This implied a high computational cost due to the large number of simulations (more than 50 000), which does not allow extending systematically it on other climatic conditions and other watersheds.

The present study aims at making possible to represent new watersheds and to determine their sensitivity to input parameters in other climatic and agronomic conditions by reducing the computational cost of the modeling toolkit. A metamodel (or surrogate model) developed on local conditions would allow to perform GSA with low cost yet ensuring it is based on physics. It would help users understanding the most important processes in the VFS they want to design and would increase the operational scope of the modeling toolkit. We performed a much smaller sampling (between 100 and 1000 combinations) of input parameters using the Latin Hypercube Sampling method optimized with a maximin criteria. The metamodel will then be based on a Kriging approach (Rasmussen and Williams, 2006). We will particularly focus on two methodological questions: (i) Is Kriging able to deal with qualitative variables (such as type of soil or type of climate)? (ii) How to integrate the dynamical aspect of state variables in the surrogate construction? The Kriging performance will be analyzed by comparison with other metamodeling methods (Random forest, GAM, linear models; Hastie et al, 2009) and validated with the physically-based simulations conducted on a full factorial test design. Once the metamodel validated, we will assess how the metamodel is a relevant tool to compute global sensitivity analysis in new conditions. Finally, the metamodel will be encapsulated in a user-friendly web interface and will allow comparison of field scenarios, and validation/improvement of actual existing VFS placements and sizing.

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