Adapting LISEM to improve modelling of pesticide transport by runoff and erosion

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Introduction

Surface runoff and erosion represent major processes of pesticide transport from agricultural land to aquatic ecosystems. Even if pesticide runoff models have been steadily improved in recent years, they remain partially successful. This could be explained by their limited ability to integrate (i) the spatial variability of pesticide deposition after application, (ii) erosion processes and (iii) the partitioning of pesticides between the dissolved and particulate phases. The objective is, therefore, to develop a simple modelling approach to predict the pesticides mobilisation from the near surface soil layer and partitioning in runoff.

Methodology

The Limburg Soil Erosion Model (LISEM) was chosen to develop this new pesticide module. LISEM is a fully distributed hydrological and soil erosion model that provides event-based predictions for small agricultural catchments. This model was specifically designed to describe the agricultural landscape components and their impact on runoff and erosion with high resolution rainfall data. LISEM was validated for different soil and land use contexts (e.g. Kvaerno, 2012; Nearing, 2005). Pesticide mobilisation at the soil/water interface is predicted by assuming that there exists a very thin layer at the soil surface where water from infiltration, runoff and soil pore mix instantaneously. A first order kinetic reaction was used to describe pesticide sorption/desorption (Wallender, 2008).

$$h\frac{\partial C}{\partial t} + uh\frac{\partial C}{\partial x} = K(C_M - C) - rC \text{ (Eq. 1)}$$

$$n\varepsilon\frac{\partial C_M}{\partial t} = K(C - C_M) + f(C - C_M) - \varepsilon\rho_b k_r(K_D C_M - C_S) \text{ (Eq. 2)}$$

$$\frac{\partial C_S}{\partial t} = k_r(K_D C_M - C_S) \text{ (Eq. 3)}$$

where h is the water depth [cm], u the average velocity of runoff [cm min^{-1}], r the precipitation rate [cm min^{-1}], f the infiltration rate [cm min^{-1}], K the film transport coefficient [cm min^{-1}]; k_r the rate of desorption [min^{-1}], K_D the soil water partition coefficient [cm^3 g^{-1}], C the pesticide concentration in runoff [µg cm^{-3}], C_M the pesticide concentration in the mixing zone [µg cm^{-3}], C_s the mass of pesticides sorbed per dry unit weight of soil [µg g^{-1}], n the soil porosity [cm^3 cm^{-3}], ε the mixing layer depth [cm] and ρ_b the soil bulk density [g cm^{-3}].The system of equations from Joyce (2008) was enhanced by adding transport of suspended solids which are contaminated by pesticides. The hypothesis was that the concentration on suspended solids was equal to C_s. Implicit finite upward difference scheme (Eq. 1) and Laplace transforms (Eq. 2 and 3) were used to solve the system of equations.
Benchmarks were first used to validate implementation of Equations 1 to 3 with experimental data from Wallender et al. (2008) at the plot scale. The modified LISEM was then applied to a 47 ha agricultural catchment with corn, wheat and sugar beet (Alsace, France) where chloroacetamides were applied. The temporal variability of the input parameters such as

saturated hydraulic conductivity, Manning's coefficient and random roughness during the growing season were estimated using the Runoff Indicator (Van Dijk, in prep). LISEM was linked to the PEST parameter estimation environment (Doherty, 2006) to perform calibration and sensitivity analysis first on hydrology and erosion parameters then on pesticides parameters.

Results and discussions

Nineteen rainfall events were monitored from 12 March to 15 August 2012, which amounted to 335 mm. Among these events, 10 produced runoff of more than 10 m^3. Runoff coefficients of these events ranged from 0.2 to 57%. These 10 runoff events were calibrated in constraining the ranges of input parameters around the values given by the Runoff Indicator. The Nash coefficient ranged from 0.40 to 0.97. The observed hydrographs and water pathways could be compared with observed data and pictures (Fig.1).

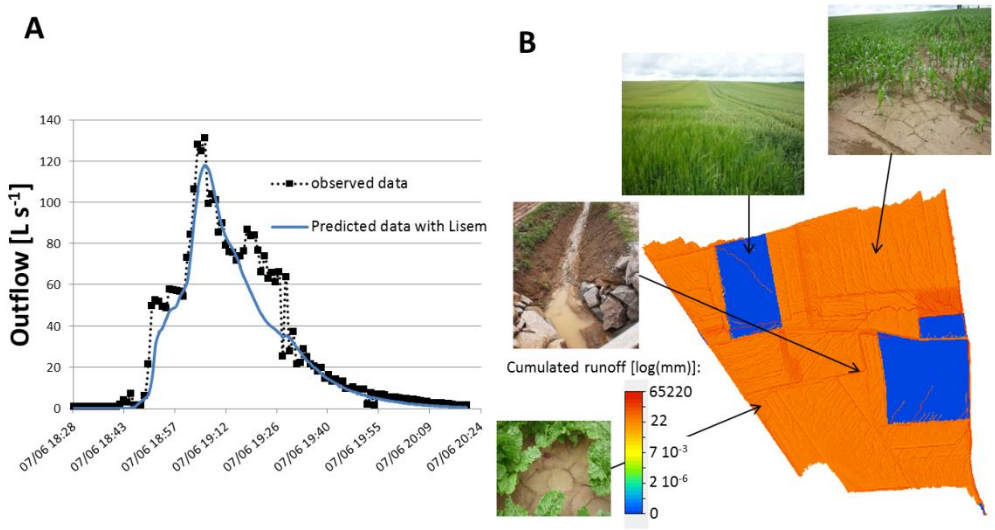

Figure 1. Simulated and observed hydrographs (A) and water pathways (B) on June 7 2012.

Conclusion

Results show that the model was able to simulate the dynamics of discharge at the outlet of the catchment over time. These results were obtained 1) by using the Runoff Indicator to predict the temporal evolution of vegetation and soil surface properties between rainfall runoff events and 2) by calibrating LISEM parameters for each rainfall-runoff event with PEST. The adopted formalism for predicting pesticide transport enables the sorption-desorption process during the rainfall-event event to be taken into account. The next steps will assess pesticide transport within the catchment and identify the period and areas for herbicide off-site transport and their partitioning between dissolved and particulate phases.

References

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