Development of an operational tool to simulate pesticide transfer through vegetated strips: the 2D runoff part

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Introduction

Well-designed vegetative filter strips can be a solution to mitigate fluxes of pesticides from agricultural plots. Modelling can help in proportioning and positioning these structures. The aim of this work is then to provide to the French decision makers a modeling tool simple enough to be operationally used to assist them in the implementation of these buffer zones. This paper presents the first step, that is to say the runoff part on a grass strip topography in two dimensions.

Materiel and method

This tool uses Richards and Kinematic wave equations to describe respectively subsurface and surface processes and their interactions. Richards equations are solved on each soil column with the Ross method (Ross, 2003). These columns will be coupled to take into account lateral flows in water tables. Kinematic wave calculations are solved in two-dimensional form, using a finite volume method and an uncentred Euler scheme. The requirement to simulate runoff in 2 dimensions is justified by many situations encountered in France: slopes in several directions on a same grass strip but also talwegs or tyre tracks which can concentrate the runoff and accelerate it, minimizing the efficiency of the buffer strip in function of their localization and direction. The model has been compared in one dimension to the VFSMOD model, which describes hydrology, sediment and pollutant transport through vegetative filter strips and is mainly validated (Munoz-Carpena et al., 1993).

Results

Figure 1 shows the Iwagaki test, which represents the most famous test to check if a code solving the kinematic wave is robust against hard changes of slopes or roughness. It consists in simulating three rains in the same time in three different parts of the grass strip, with three values of Manning's coefficient for the roughness (0.015; 0.01; 0.02). This simulation is compared to data from Iwagaki (1955) and to VFSMOD simulations. Our finite volumes scheme gives good results, coherent with the data and quite good fit with VFSMOD simulation. The code proves to be robust against kinematic shocks.

Figure 1. Iwagaki test to check the kinematic wave solving code robustness: comparison of the code with data experiments (stars) and VFSMOD simulation (blue line).

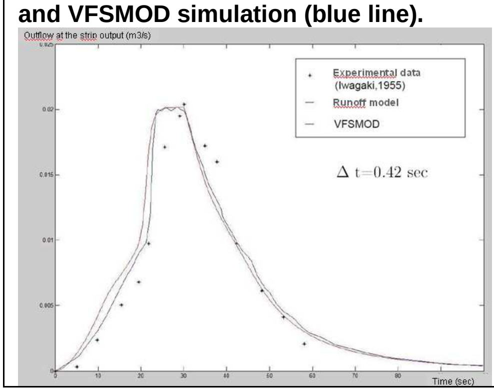
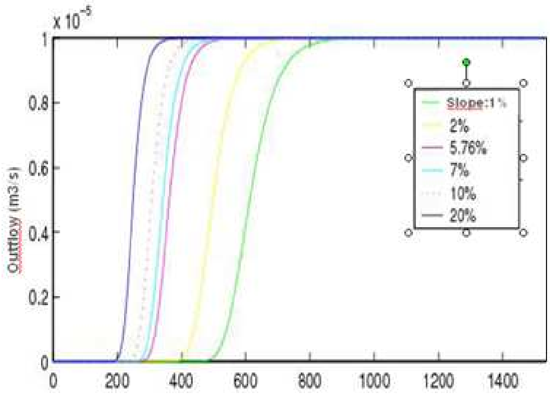


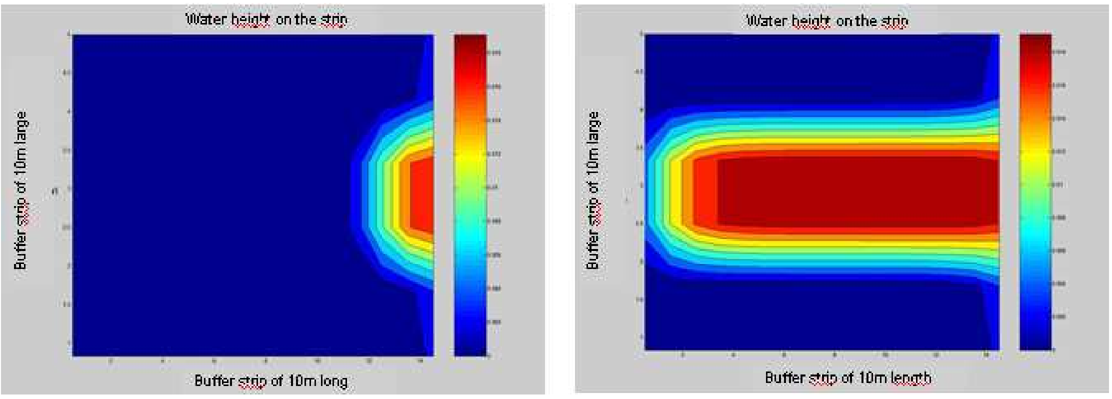
Figure 2. Sensitivity analysis of the output flow (m^3/s) to the slope, from 1% to 20%.



A simple sensitivity analysis was performed for several input parameter values to test the model robustness and coherence to input variation. Figure 2 shows the sensitivity of the output flow to the slope, which varies from 1% to 20%. Results show as expected that the most important is the slope, the more rapidly the outflow reaches the stationary state, but also that even for sharp slopes (20% is quite rare for grass strips), the code is still stable and ensures very good mass balances.

Finally, simulations of the runoff on grass strips have been performed in 2 dimensions. As no runoff data are available in 2 dimensions to validate the code, observations of the outflow and mass balance permit to check the logical behaviour of the model. Figure 3 shows a test where the grass strip contains a talweg from East to West, in the same direction as the incoming flow (from East). The flow begins to concentrate in the talweg close to the beginning of the simulation (left) and is more and more concentrated until the end (right), accelerating the flux and minimizing the possible effect of infiltration of the grass strip. Mass balance is very good (error of 10^{-13} m^3/s).

Figure 3a.-3.b. Runoff simulated in 2 dimensions on a grass strip containing a talweg with an input flux coming from right and concentrating in the talweg, at times 60s and 300s.



As a conclusion, the runoff module has been applied to several synthetic and real situations, and thereby validated. The most innovative aspect of this development lies in the 2 dimensional description of the topography, which will permit to simulate grass strips containing talwegs. It needs now to be coupled with the solution of Richards equation, as infiltration is the most important process of efficiency of grass strips. This model will then be able to be compared with other reliable complex models as a validation for the whole water part. Finally, the pesticides part will be added to this tool, which will be validated with experimental data including water tables which may, particularly in some French contexts, limit the efficiency of vegetated strips.

References

Iwagaki Y. (1955). Fundamental studies on runoff analysis by characteristics. Bull. 10, pp.1-25, Disaster Prev. Res. Inst., Kyoto Univ., Kyoto, Japan.

Munoz-Carpena R. (1993) Numerical approach to the overland flow process in vegetative filter strips - American Society Of Agricultural Engineers: General Edition Volume: 36 Issue: 3 p. 761-770.

Ross PJ. (2003) Modeling soil water and solute transport – fast, simplified numerical solutions. Agron J;95:1352–61.