Effect of Remobilization of Pesticide Residues in Vegetative Filter Strips for Pesticide Mitigation in Higher-Tier Exposure Assessments with VFSMOD

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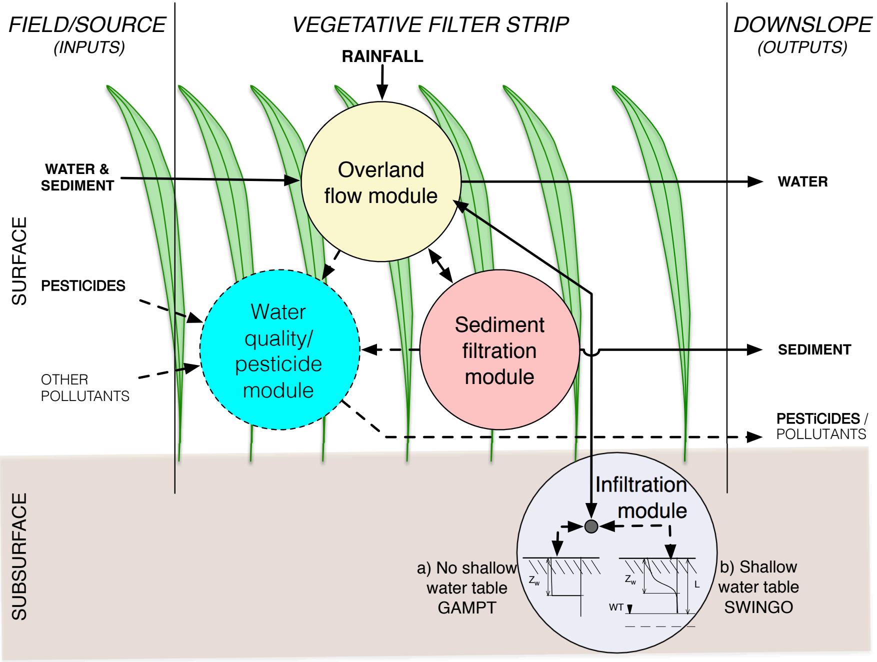
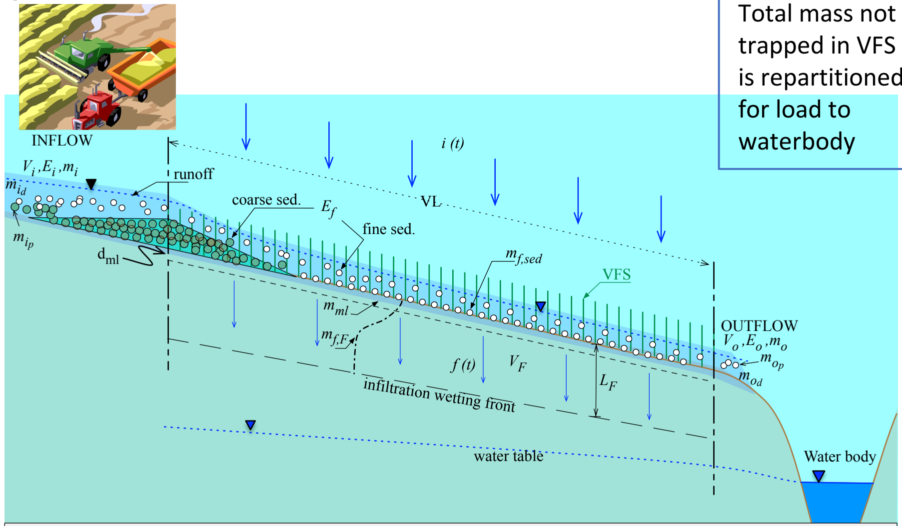
Quantitative runoff pesticide mitigation

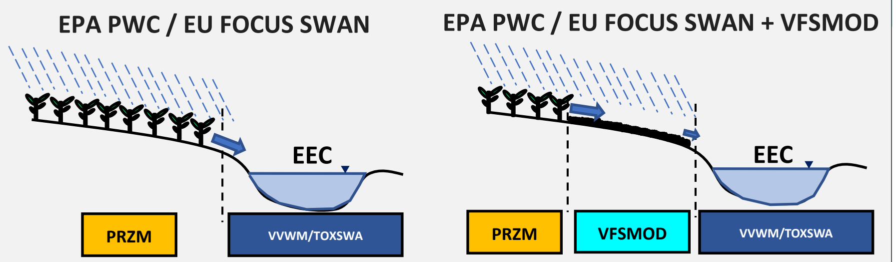
VFSMOD: Vegetative filter strip modeling system



[Muñoz-Carpena et al. 1999. *J Hydrol*. 214:111– 129]

Total mass not trapped in VFS is repartitioned for load to waterbody





https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment

Sabbagh et al., 2010, *Env. Sci & Tech.* 44:3839-3845; Sabbagh et al., 2013. *Chemosphere* 90(2):195-202; Muñoz-Carpena et al., 2015, *Chemosphere* 139:410-421.

Motivation

- After initial trapping of runoff pesticides in the vegetative filter strip (VFS), fate of surface pesticide residues is complex undergoing degradation, remobilization in a subsequent event, and retention of part of the mass in the surface (carry over).
- A revised mechanistic mass-balance and remobilization scheme is justified based on some EEAs results with special chemical compounds.
- In particular, the correct quantification of remobilization might be important for very highly sorbed compounds (K_{oc} >100000), particularly pyrethroids and other.
- There is a need for a general mechanistic solution for all compounds, not capricious for different types of K_{oc}.
- Currently, VFSMOD makes a risk conservative assumption of remobilizing 100% of the residues trapped on the VFS surface from the last event, after degradation during the rainfall hiatus (Muñoz-Carpena et al., 2015).

Muñoz-Carpena, R. A. Ritter, G.A. Fox and O. Perez-Ovilla. 2015. Does mechanistic modeling of filter strip pesticide mass balance and degradation affect environmental exposure assessments? *Chemosphere* 139:410-421. doi:10.1016/j.chemosphere.2015.07.010

New VFSMOD surface pesticide residues remobilization

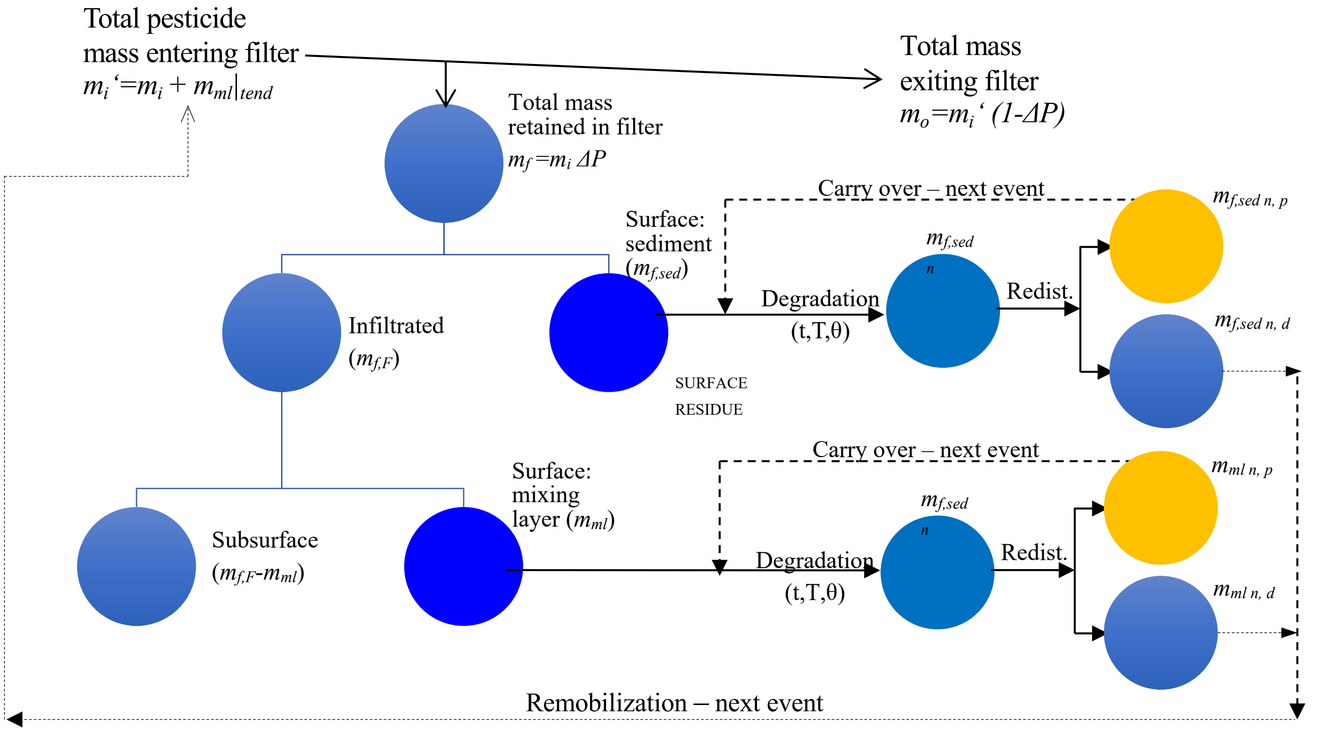
- Four alternative schemes (IMOB1-IMOB4) are developed in VFSMOD to be tested against subset of field data compiled by Reichenberger et al. (2019)
- The schemes are built on the new VFSMOD mechanistic pesticide trapping equation (Reichenberger et al., 2019; Muñoz-Carpena et al., 2019) and existing degradation processes (Muñoz-Carpena et al., 2015; 2018)
- Encompass 2 remobilization options (IMOB1—2) for dissolved and solid phases of surface pesticide retained at the filter, and 2 control options for comparison (IMOB3—4).
- The remobilization schemes include new processes:
    - non-linear transport into the soil to quantify fraction of infiltrated (dissolved phase) pesticide retained in mixing layer.
    - carry-over to the next runoff event in the time series

Reichenberger, S., Sur, R., Kley, C., Sittig, S, Multsch, S., 2019. Recalibration and cross-validation of pesticide trapping equations for vegetative filter strips (VFS) using additional experimental data. *Science of the Total Environment* 647, 534-550.

Muñoz-Carpena, R., A. Ritter, G. Fox. 2019. Comparison of empirical and mechanistic equations for vegetative filter strip pesticide mitigation in long-term environmental exposure assessments. *Water Research* 165:1149833. doi:10.1016/j.watres.2019.114983

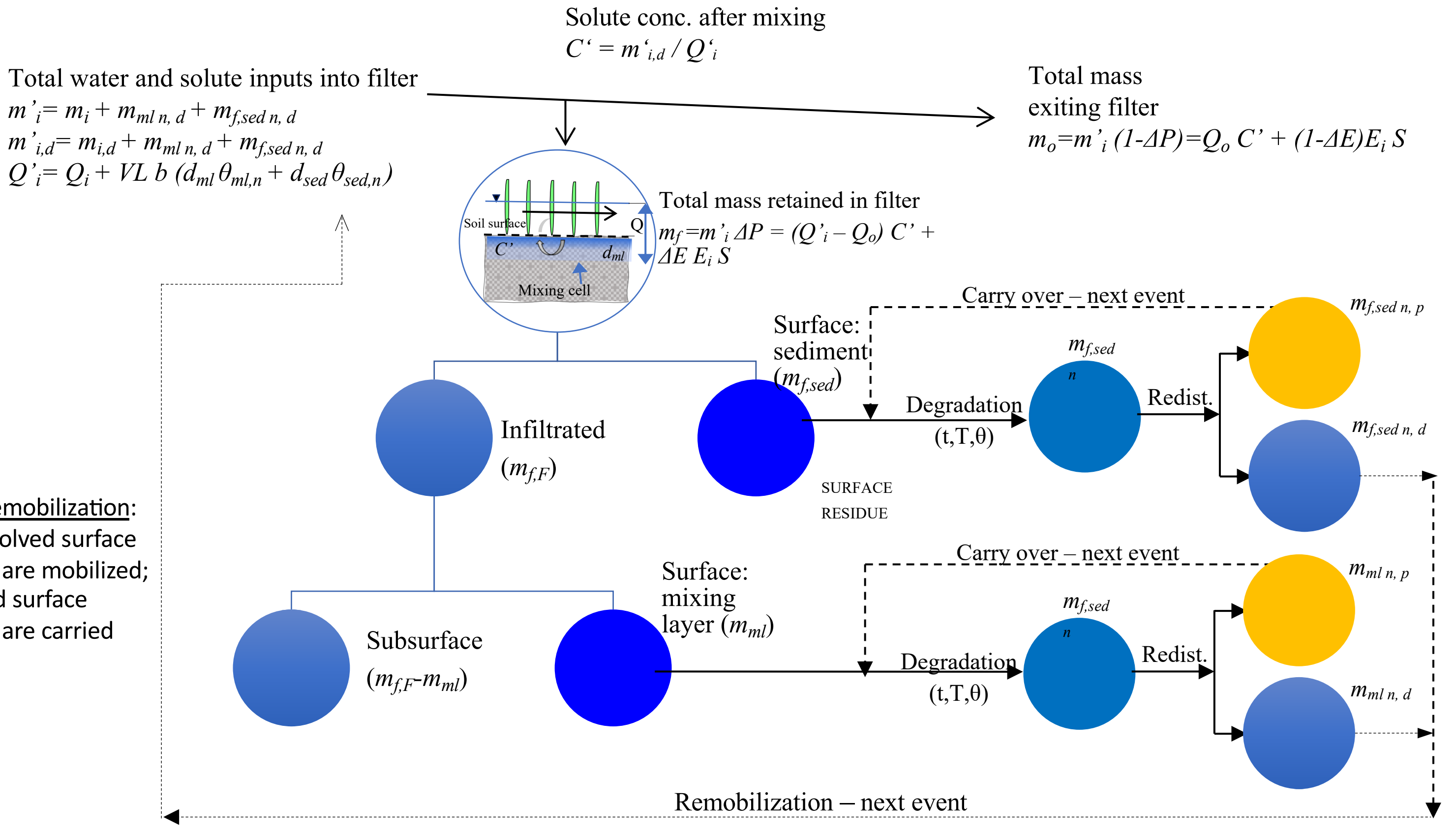
Muñoz-Carpena, R., G. Fox, A. Ritter, I. Rodea-Palomares. 2018 .Effect of vegetative filter strip pesticide residue degradation assumptions for environmental exposure assessments. *Science of the Total Environmen*t 619–620:977–987, doi:10.1016/j.scitotenv.2017.11.093

IMOB1: Remobilization of dissolved phase surface residues, solid phase residues are retained and carried over to next event



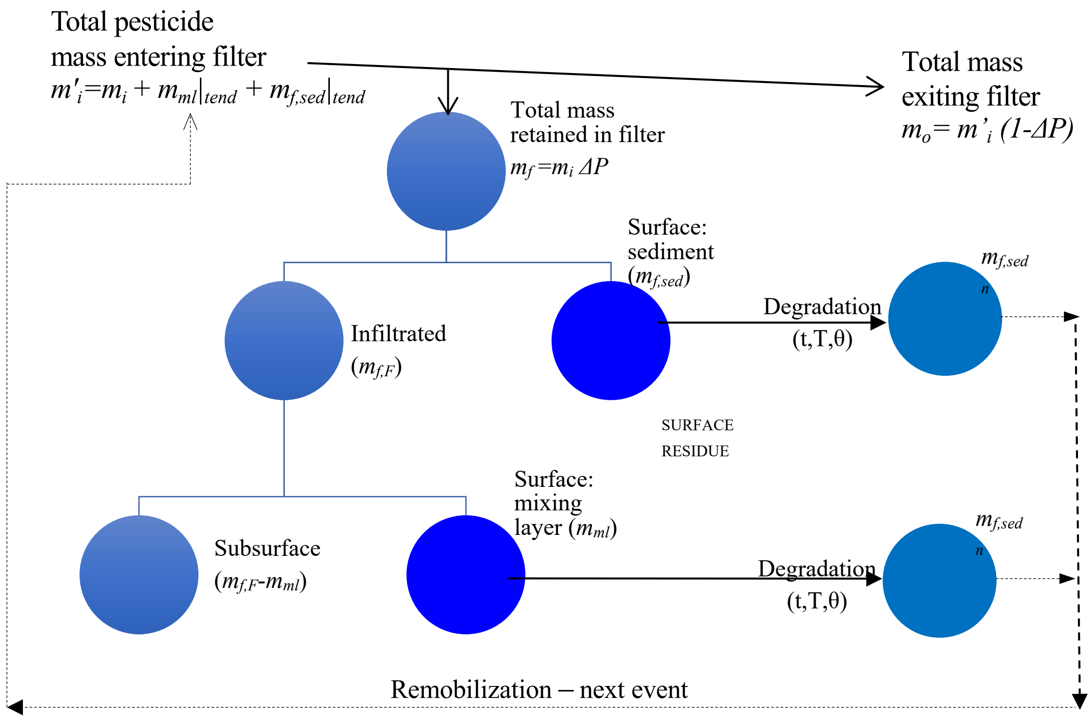
<u>Partial remobilization</u>: only dissolved surface residues are mobilized; adsorbed surface residues are carried over

IMOB2 : Complete mixing of run-on, rainfall and pore water in mixing layer and sediment layer → trapping and remobilizaton of dissolved residues at the same time.



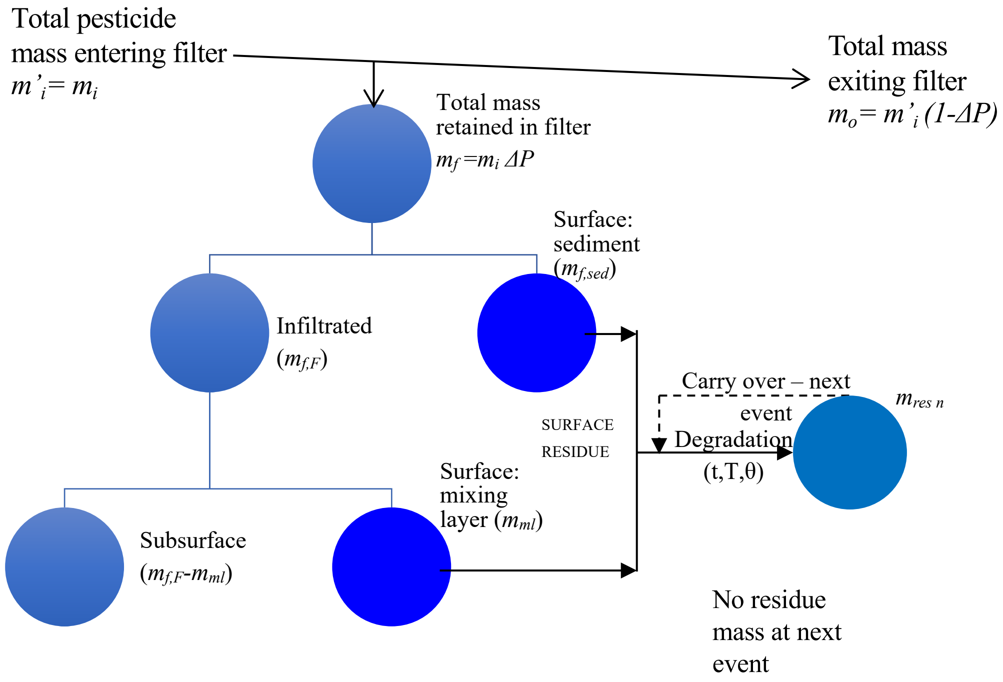
<u>Partial remobilization</u>: only dissolved surface residues are mobilized; adsorbed surface residues are carried over

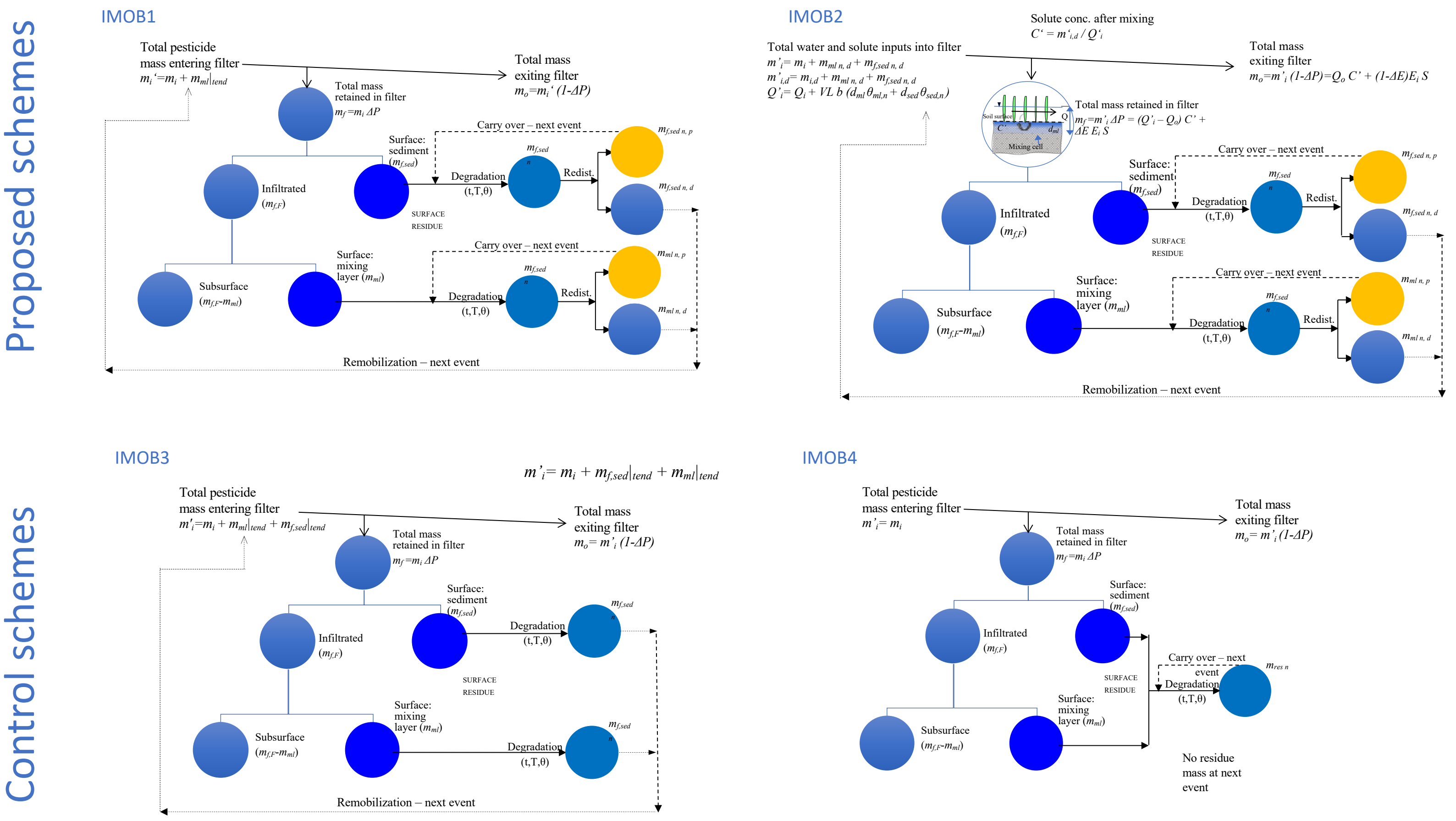
IMOB3: 100% surface residue remobilization of both solid and dissolved phases



<u>Full remobilization</u>: dissolved and sorbed surface residues are remobilized and added to runoff in the next event

IMOB4: No pesticide residue mobilization

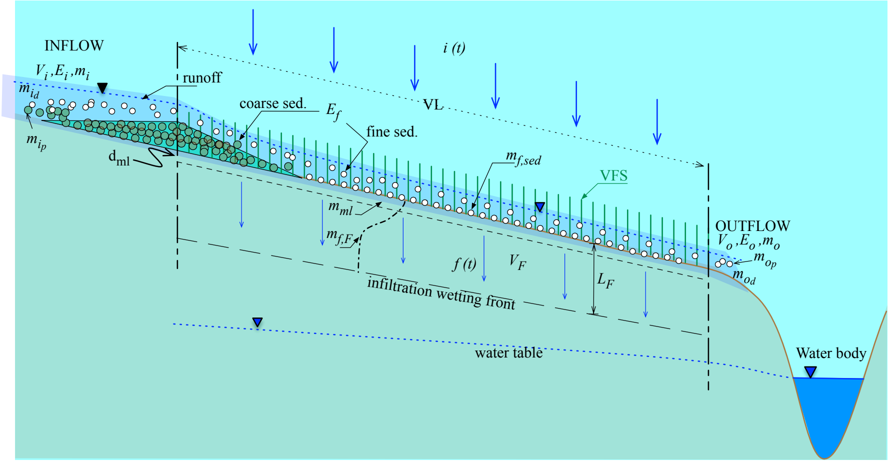


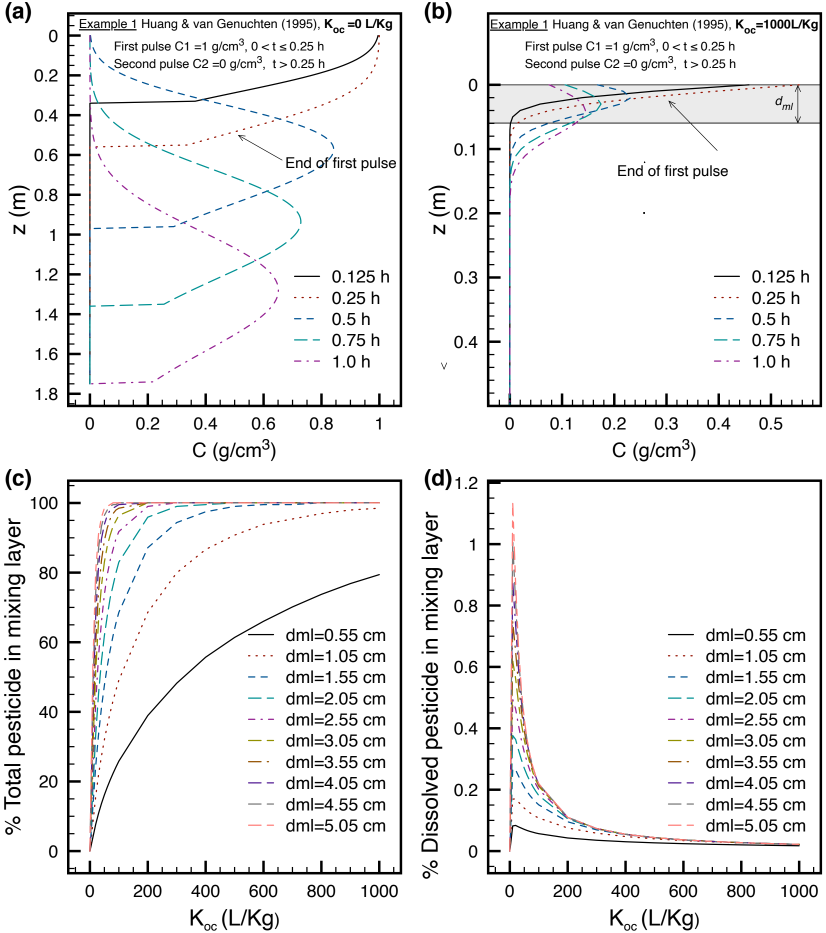


Proposed schemes
IMOB1
Total pesticide mass entering filter
$m_i' = m_i + m_{ml}|_{tend}$
Total mass exiting filter
$m_o = m_i' (1-\Delta P)$
Total mass retained in filter
$m_f = m_i \Delta P$
Surface: sediment ($m_{f,sed}$)
Infiltrated ($m_{f,F}$)
SURFACE RESIDUE
Carry over – next event
Degradation (t,T,θ)
Redist.
$m_{f,sed\,n}$
$m_{f,sed\,n,p}$
$m_{f,sed\,n,d}$
Surface: mixing layer (m_{ml})
Subsurface ($m_{f,F}-m_{ml}$)
$m_{ml\,n,p}$
$m_{ml\,n,d}$
Remobilization – next event
IMOB2
Solute conc. after mixing
$C' = m'_{i,d} / Q'_i$
Total water and solute inputs into filter
$m'_i = m_i + m_{ml\,n,d} + m_{f,sed\,n,d}$
$m'_{i,d} = m_{i,d} + m_{ml\,n,d} + m_{f,sed\,n,d}$
$Q'_i = Q_i + VL\, b\, (d_{ml}\theta_{ml,n} + d_{sed}\theta_{sed,n})$
Total mass exiting filter
$m_o = m'_i (1-\Delta P) = Q_o C' + (1-\Delta E) E_i S$
Total mass retained in filter
$m_f = m'_i \Delta P = (Q'_i - Q_o) C' + \Delta E\, E_i\, S$
Soil surface
Mixing cell
Control schemes
IMOB3
$m'_i = m_i + m_{f,sed}|_{tend} + m_{ml}|_{tend}$
Total pesticide mass entering filter
$m'_i = m_i + m_{ml}|_{tend} + m_{f,sed}|_{tend}$
Total mass exiting filter
$m_o = m'_i (1-\Delta P)$
IMOB4
Total pesticide mass entering filter
$m'_i = m_i$
Total mass exiting filter
$m_o = m'_i (1-\Delta P)$
Carry over – next event
$m_{res\,n}$
No residue mass at next event

Non-linear distribution of pesticide residue in mixing layer

A new vertical pesticide leaching with sorption component added to VFSMOD based on the analytical solution of the convective-dispersive transport equation (CDE) within the infiltration wetting front and numerical integration for mass retained within the mixing layer depth d_{ml}.





Huang, K. and M.Th. van Genuchten. 1995. An analytical solution for predicting solute transport during ponding infiltration. Soil Science, 159(4):217-223

Lindstrom, F. T., R. Haque, V. H. Freed, and L. Boersma. 1967. The movement of some herbicides in soils: Linear diffusion and convection of chemicals in soils. *Environ. Sci. Tech.* 1(7): 561-565.

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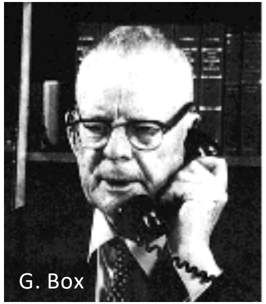
On going work

- Code testing and documentation
  - Selection continuous benchmark events to test changes introduced by IMOB
  - Selection of outputs of interest to test remobilization effects
- Testing with multi-event field studies data from Reichenberger et al. (2019)
  - Selection and parametrization
  - Testing process
- Evaluation of important pesticide residue remobilization factors with representative EEAs through global sensitivity analysis

Conclusions

- System-wide assessment of important factors controlling pesticide mitigation with VFS is critical in higher-tier risk assessments (complex problem)
- A physically consistent and robust description of pesticide residues on the VFS surface after the runoff is important to provide realistic mitigation.
- Objective identification of important drivers requires consideration of all factors present (physical, chemical and plants)
- Consideration of in-situ field characteristics leads to realistic assessment of mitigation efficiency
- Field testing with data set and EES scenarios is critical to ensure the validity of the new pesticide residue fate component and the safe use of plant protection products that address societal concerns about the persistence and risk of pesticides in the environment.

‘…all models are wrong, some are useful’



‘… and remember – GIGO!!’