Impact of soil management in ditches on water related ecosystem services

Cécile Dagès, Jean-Stéphane Bailly, Jeanne Dollinger, Marthe Lanoix, David Crevoisier, Marc Voltz

Impact of soil management in ditches on water related ecosystem services.

Cécile Dagès[1], Jean-Stéphane Bailly[2], Jeanne Dollinger[1], Marthe Lanoix[1], David Crevoisier[1], and Marc Voltz[1]

(1) INRA, (2) AgroPariTech,
2 place Pierre Viala, F-34060 MONTPELLIER CEDEX 1, France
*Corresponding author: cecile.dages@supagro.inra.fr
www.umr-lisah.fr

Ditches, providers of regulating ecosystem services

Farm ditches are human-made linear elements that constitute the upstream parts of the permanent hydrographic networks in agricultural landscapes. Primarily implanted to collect surface and subsurface water for soil waterlogging and/or erosion control, farm ditches may also provide other services such as water purification, flood regulation, groundwater recharge, and biodiversity conservation (Dollinger et al., 2015).

By changing ditch characteristics, ditch maintenance operations (fig 1) influence the provision of ecosystem services. The project presented in this poster aimed to investigate the impact of ditch management on water related ecosystem services, notably water purification against pesticides.

We focus on infiltrating ditches because of their ambivalent position: they are known to buffer surface water pesticide contamination, but they may also contribute to groundwater contamination.

fig 1. Ditch maintenance, a combination and a succession in time of basic operations

We follow a 3 steps approach:

1- Characterization of ditches variability by building classifications of ditch characteristics and by linking ditch types with maintenance operation.

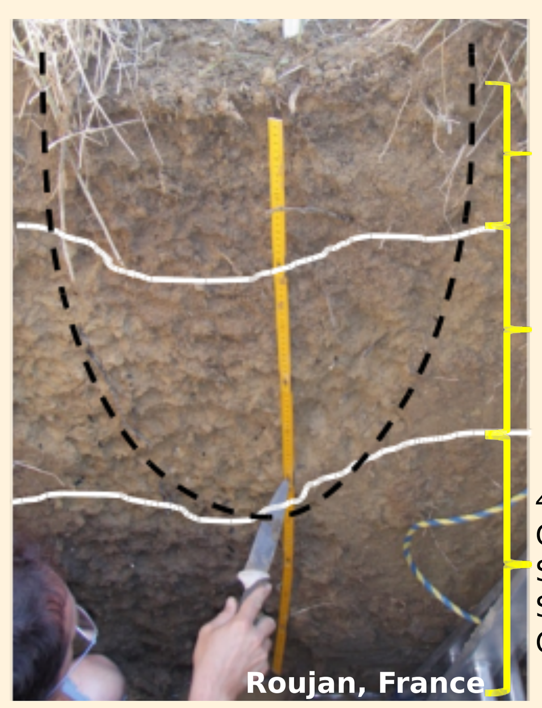
2- Analysis of retention capacity at the reach scale with an indicator based approach to asses range of retention capacities and virtuous/bad types.

3- Analysis of the retention capacity at the network scale with a distributed physically based modelling approach to evaluate management strategies.

Ditch bed soils

Ditch bed soil's are formed from layered fine sediments deposited by surface flow structured by wetting/drying cycles and root activity (Vaughan et al., 2008)
.
Their characteristics are different from neighbouring soils : porous structure, infiltration properties or organic matter content (Margoum et al., 2006; Dagès et al., 2015).

Example of a ditch bed soil



0-17 cm
Clay: 29%
Silt: 48%
Sand: 23%
OM: 2.94%
BD: 1.28

17-45 cm
Clay: 28%
Silt: 36%
Sand: 36%
OM: 2.7%
BD: 1.35

45-80 cm
Clay: 30%
Silt: 61%
Sand: 9%
OM: 1.4%

A granular structure with high porosity and few very coarse fragments occurred in each horizon.

How to differentiate ditches against pesticide transfer behavior?

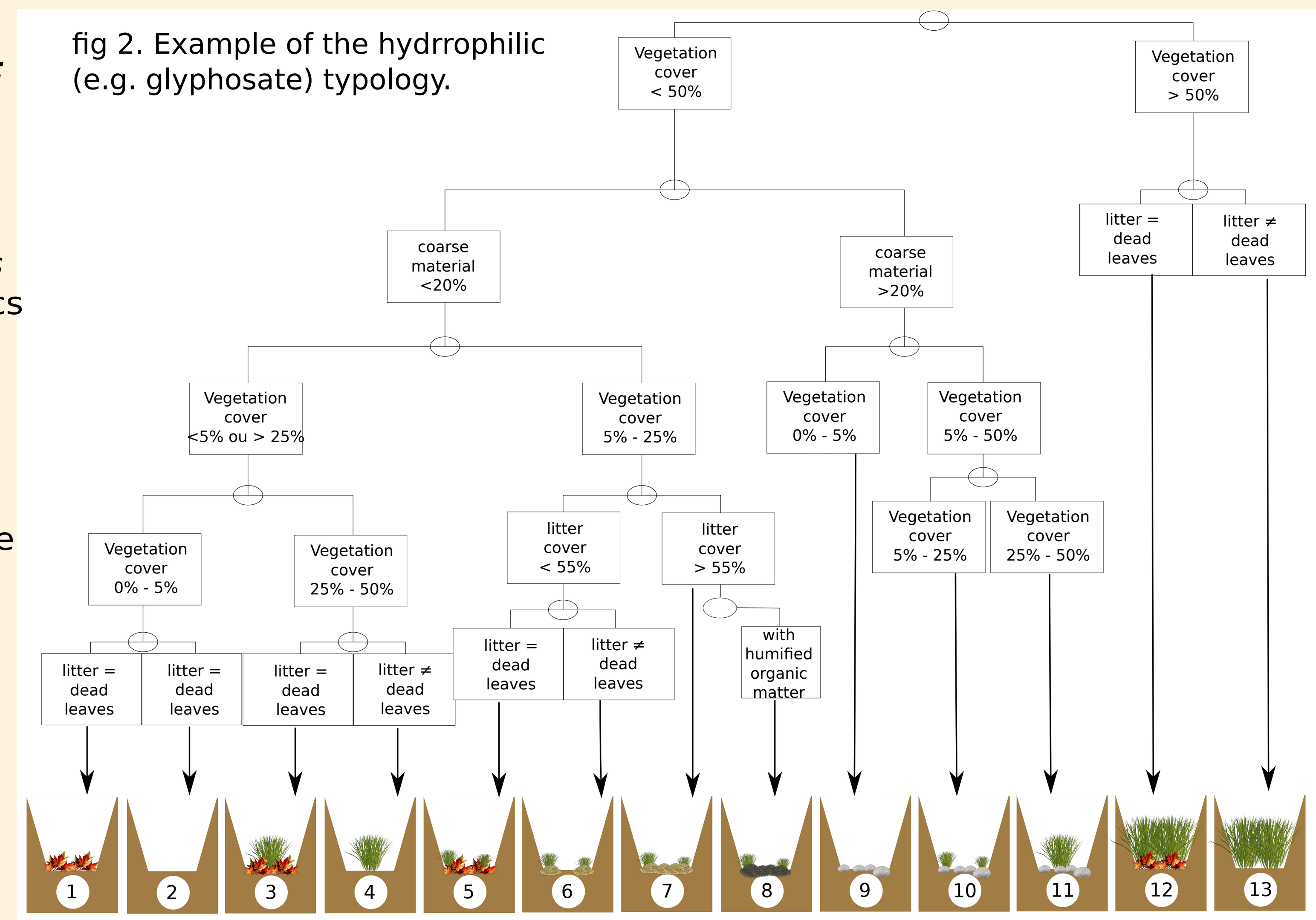
Classifications of ditch characteristics were built to discriminate ditches following their properties influencing pesticide transfer, based on :

- *Measurement of sensitive parameters:*
  infiltrability,
  roughness,
  sorption coefficient

- *~1000 observations* of ditch characteristics from 3 catchments.

- *Statistical analyses* (CAH, CART) to create a global typology per pesticide water affinity:
  hydrophilic (fig 2),
  hydrophobic and
  super-hydrophobic

fig 2. Example of the hydrrophilic (e.g. glyphosate) typology.



Each type is a result of a ditch maintenance operation and a natural evolution in relation with the climate. Transition matrix between types after maintenance were also built (see fig 3).
The method and the results are detailled in Bailly et al., (2015).

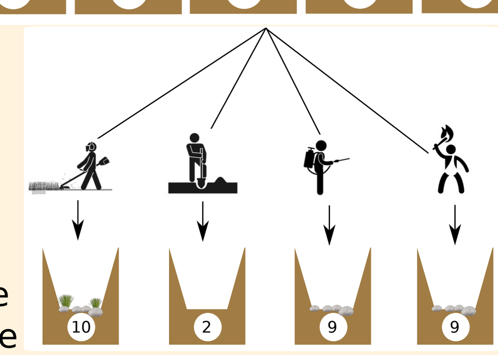


fig 3. Example of the type change after maintenance

Simulating reach scale retention with an indicator approach

A sensitivity analysis was performed at the reach scale to assess the range of retention variablity and to identify virtuous / bad types of ditch. Simulation were performed with an indicator approach.

A semi-quantitative indicator based approach
(adapted from Dollinger et al., submitted)

- Based on a *reach segment* mass balance
- Equilibrium with linear sorption and similar kinetics
- Massic proportion of sorbing ditch material deduced from cover rate

Design of the sensitivity analysis

- Sobol sequences, 8 factors, 40 000 simulations

- ditch type
- width
- soil type
- slope
- *initial soil moisture*
- soil sorption
- inflow
- *concentration / initial residue content*

Sorption coefficients Kd (L/kg) - Glyphosate

- dead leaves : 4
- living leaves : 2
- ashes : 24
- soil : 24 - 320

A large range of retention capacities

Fig 4-6 illustrate the sensitivity of ditches for the hydrophilic classification (fig2).
Soil Kd and width are the most sensitive parameters. Effect of type is not clear for this classification, unlike for the other two classifications.

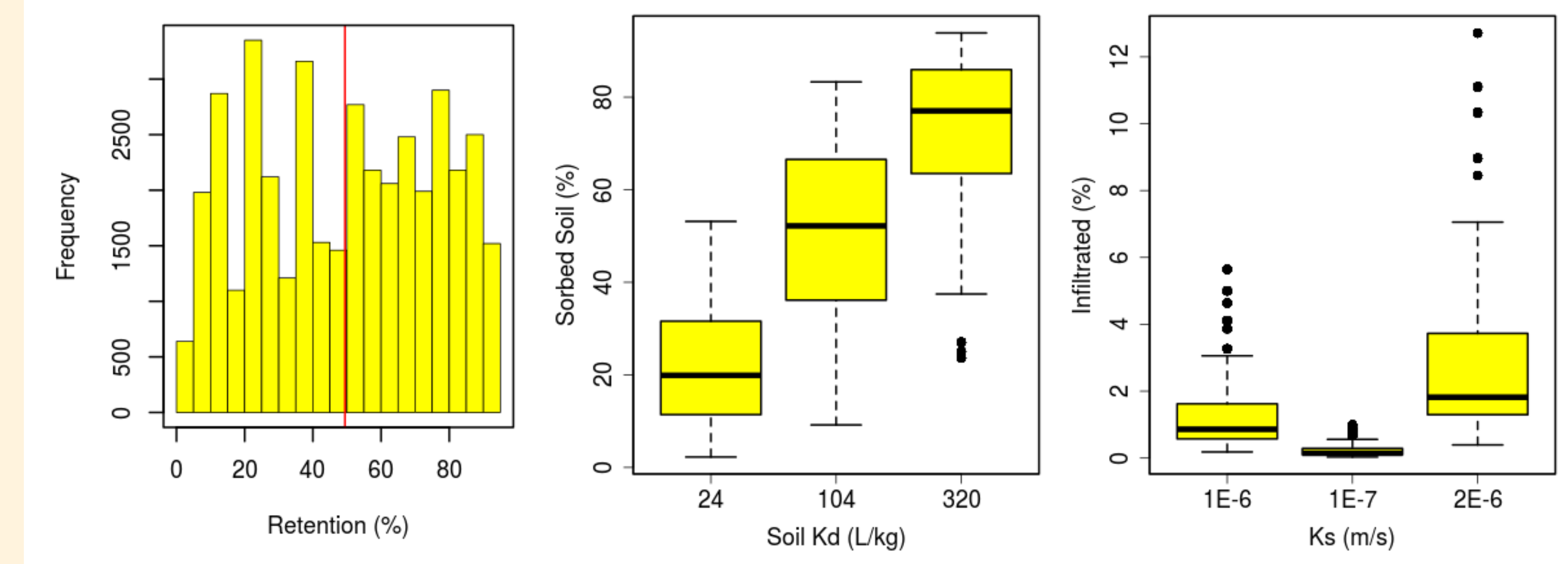


fig 4. Distribution of ditch retention

fig 5. Major effect of soil Kd on ditch retention

fig 6. Minor effect of infiltration on ditch retention

Simulating network retention with a spatially distributed modeling approach

Analysing scenarii at the network scale is essentiel to evaluate management strategies.

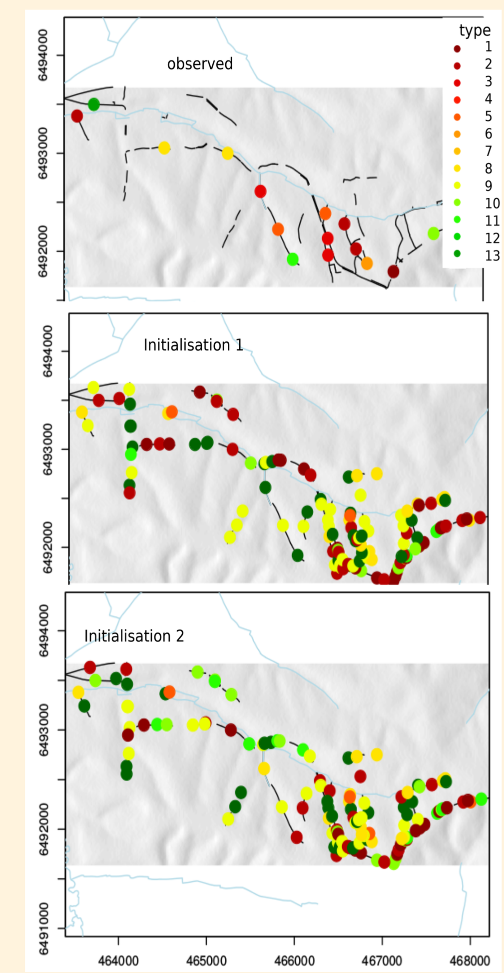
Prediction of the distribution of ditch types within the network

- Method: Supervised classification (Biarnès et al., 2009)
--> probability distribution per ditch reach

- Landscape covariables:
  - from DEM : slope, normalized altitude, Multi Resolution Valley Bottom Flatness index (Gallant and Dowling, 2003)
  - from soil map : soil type
  - from ditch network map : ditch location

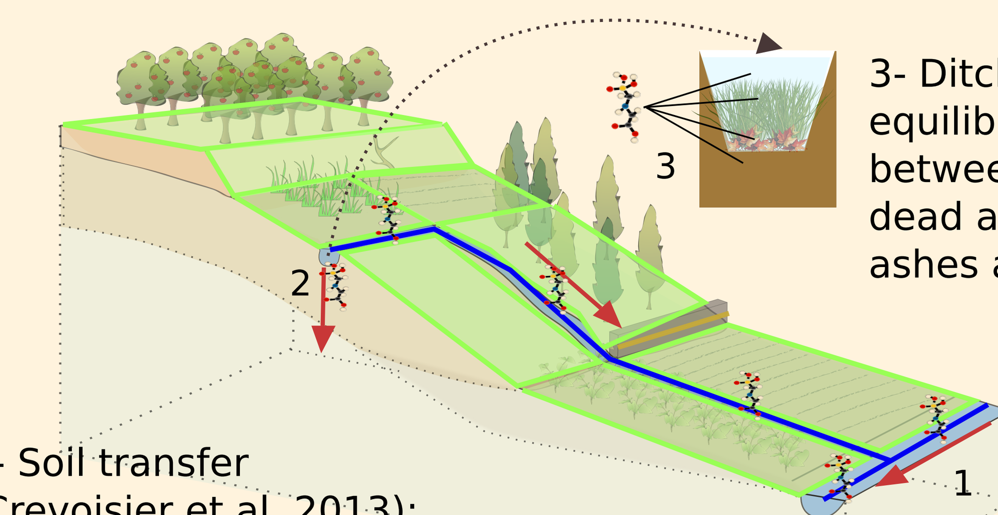
Application

- Ruiné catchment (France), 5.8 km², ditch density: 2.4km/km²
- Hydrophilic types distribution



A physically based approach

Coupling of surface and subsurface water flow and reactive solute transport within the OpenFLUID coupling plateform framework (Fabre et al., 2010) :



3- Ditch pesticide distribution: equilibrium and linear sorption between free water column, dead and leaving vegetation, ashes and topsoil

2- Soil transfer (Crevoisier et al. 2013):
a) 1D water flow ;
b) 1D reactive solute transfer, linear sorption, 1st order degradation

1- Water and Solute Surface propagation (Moussa et al., 2002)

Next steps Running contrasted scenarii at the network scale

Concluding remarks

This work shows that i) ditches may be classified from basic characteristics, but that types depend on the nature of the pollutant; ii) distribution of ditch types within catchment can be predicted with simple landscape covariables; iii) soil play a key role in water ditch purification for hydrophilic molecules such as glyphosate, with soil sorption counting for 77-99% of retention capacity. Soil sorption is also a major processes for hydrophobic (diuron) and super-hydrophobic molecules (chlorpyrifos), but other ditch materials, respectively ashes and living vegetation are significantly involved in (super)-hydrophobic molecules ditch retention. Management of ditches should be considered as a valuable tools to limit water contamination.

References

Bailly, J.S. , Dages, C., Dollinger, J., Lagacherie, P., and Voltz, M. (2015b). Protocole de spatialisation et d'évolution d'états de surface de fossés. Technical report, ONEMA-INRA.
Biarnès, A., Bailly, J.S. and Boissieux, Y. (2009) Identifying indicators of the spatial variation of agricultural practices by a tree partitioning method : the case of weed control practices in a vine growing catchment. Agricultural Systems, 99(2-3) :105–116.
Crevoisier, D. and Voltz, M. (2013). Watsfar: numerical simulation of soil water and solute fluxes using a fast and robust method. In Vol. 15, EGU2013-10296, EGU General Assembly 2013, Vienne (Autriche).
Dages, C., Samouëlian, A., Negro, S., Storck, V., Huttel, O., and Voltz, M. (2015). Seepage patterns of Diuron in a ditch bed during a sequence of flood events. Science of The Total Environment, 537:120–128.
Dollinger, J., Dages, C., Bailly, J.-S., Lagacherie, P., and Voltz, M. (2015a). Managing ditches for agroecological engineering of landscape. a review. Agronomy and sustainable developement, 35(3):999–1020.
Dollinger, J., Dagès, C., Negro, S., Bailly, J.-S., and Voltz, M. (Submitted). Variability of glyphosate and diuron sorption capacity of ditch beds.
Science of The Total Environment.
Fabre, J. C., Louchart, X., Colin, F., Dagès, C., Moussa, R., Rabotin, M., Raclot, D., Lagacherie, P., and Voltz, M. (2010). OpenFLUID : a software environment for modelling fluxes in landscapes. In LandMod, number 1, pages 1–13.
Gallant, J. C. and Dowling, T. I. (2003). A multiresolution index of valley bottom flatness for mapping depositional areas. Water Resources Research, 39(12).
Margoum, C., Malessard, C., and Gouy, V. (2006). Investigation of various physicochemical and environmental parameter influence on pesticide sorption to ditch bed substratum by means of experimental design. Chemosphere, 63:1835–1841.
Vaughan, R. E., Needelman, B. a., Kleinman, P. J. a., and Rabenhorst, M. C. (2008). Morphology and Characterization of Ditch Soils at an Atlantic Coastal Plain Farm. Soil Science Society of America Journal, 72(3):660.

Acknowledgments This work was achieved in the framework of a research and development project funded by the French Office for Water and Aquatic Bodies (ONEMA).