



call for research projects
« Phytopharmaceutical products: from exposure to impact on human health and ecosystems » »

Plot-scale modeling of pesticide fate in soil, water and air, taking into account intra-field heterogeneity in vineyard plots.

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1- INRAE Montpellier
2- INRAE Paris-Saclay
3- INRAE Avignon



Heterogeneities in vine plots enhanced by farm practices

Various soil management practices and pattern



→ heterogeneity on transfer & retention soil properties

Sprayers and Pesticide distribution

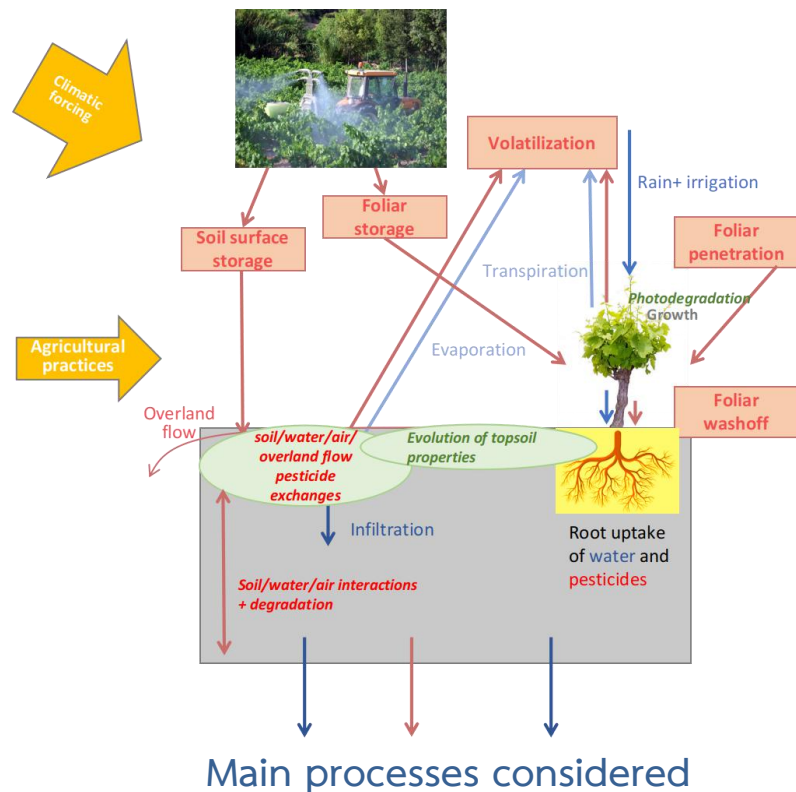


→ heterogeneity on plant/soil, row/inter-row pesticide distribution



Objective : To develop a vineyard plot pesticide fate model

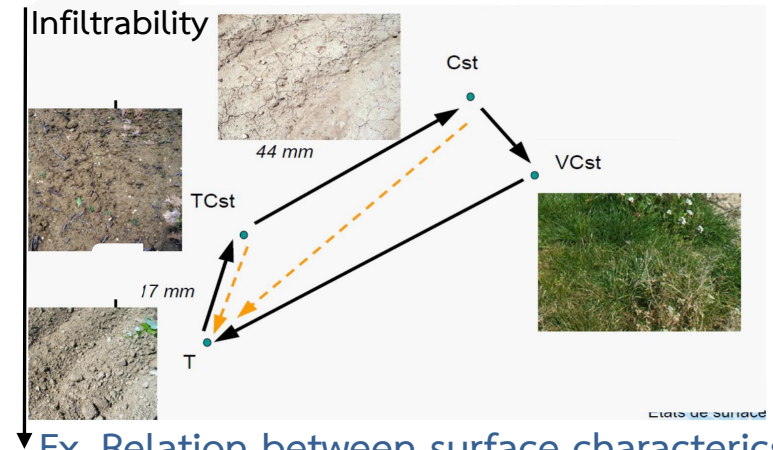
- to be used to
 - analyze the main dispersion routes and their variability as a function of pesticide properties
 - evaluate performance of new vineyard management strategies : air - soil - water contamination risk
- Specificities
 - Representation of main processes based on coupling of
 - Boundary conditions models
 - Soil surface conditions
 - Atmospheric conditions
 - Mechanistic pesticide fate model in Soil-Plant continuum
 - Spatial segmentation adapted
 - Row and Inter-Row (IR) differences
 - Process resolution needs



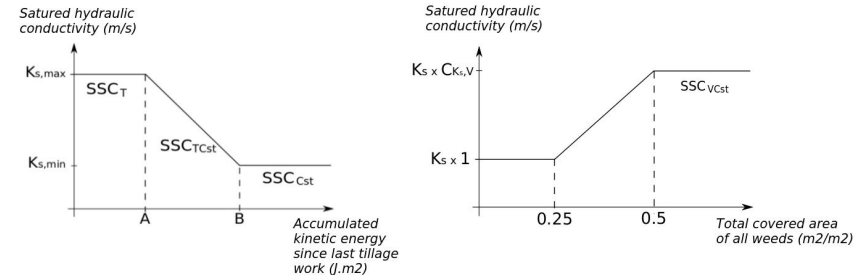
Changes in soil surface conditions due to soil treatment practices and grass growth

Simulates changes in grass cover and hydraulic conductivity

- Adapted from Paré et al., (2011)
- depending on climatic condition, soil water availability and weed control management operations
- 3 main components :
 - pluri-specific grass growth according to soil water availability
 - crust development according to rainfall kinetic energy
 - Relationship between soil hydraulic conductivity and grass cover and crust cover



Ex. Relation between surface characteristics and infiltrability



Evolution of hydraulic conductivity

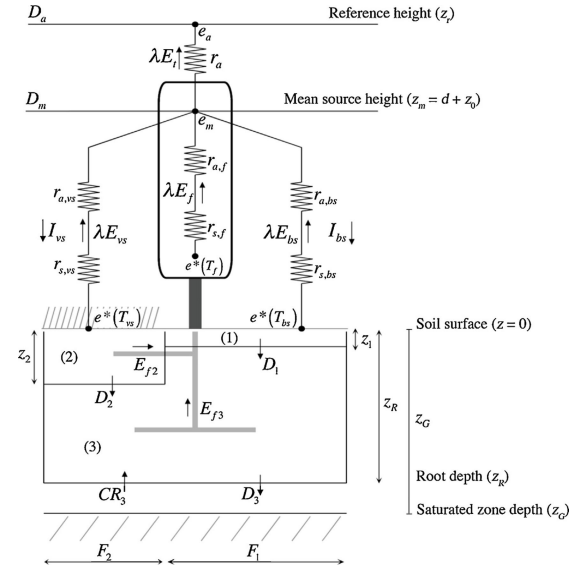
Figure 5 – Évolution de la conductivité hydraulique à saturation pour les états de surface du sol
MHYDAS Pesticides



Energy balance of a grassed vineyard

A 3 sources (soil, vine, grass) energy balance approach

- adapted from Montès et al. (2014)
- considering row / inter-row structure
- distinguishing grass transpiration, vine transpiration and soil evaporation
- calculating distinct soil, grass and vine surface temperatures and resistivities needed for volatilization simulation
- adapted to the evolution of grass cover



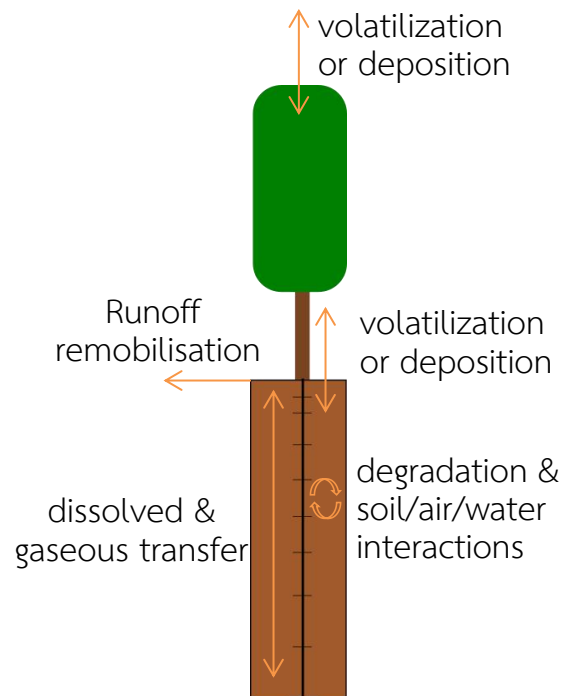
Schematic representation of the three source energy balance model (in Montès et al., 2014)



Mechanistics pesticide fate model in the soil-plant system

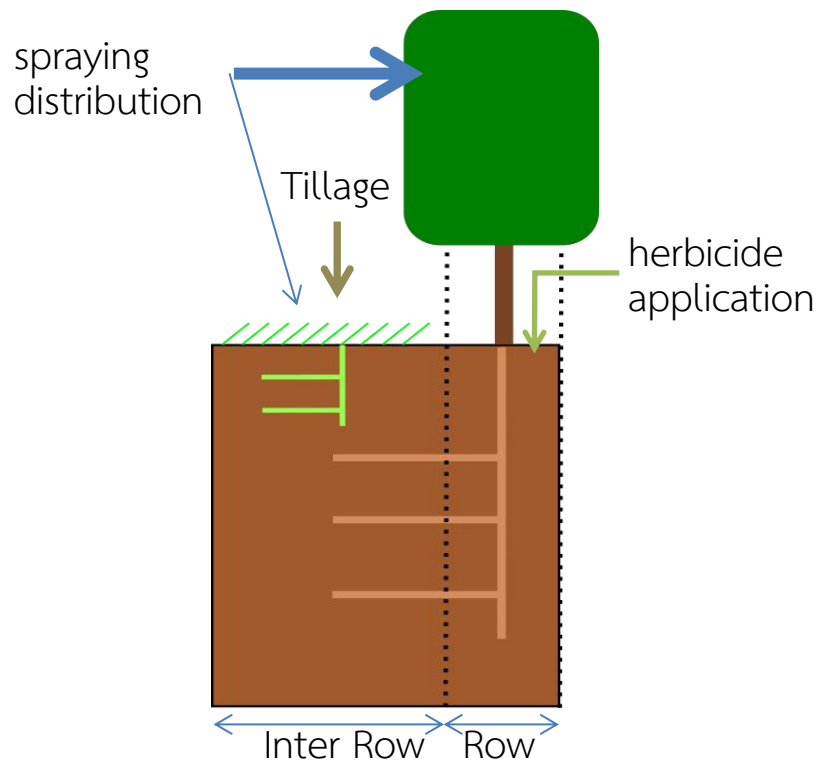
Based on the coupling of Pastis (Lafolie et al. 1991) and Volt'air (Bedos et al., 2009):

- Water and heat transfer :
 - Richards and Fourier equations
- Dissolved & gaseous pesticide soil transfers
 - CDE and Fick equations
 - Soil/gas/liquid physico-chemical equilibrium
 - First order degradation
- Volatilization from soil and leaves
 - global resistive approach
 - with leaf compartmental approach (Lichiheb et al., 2016)
- Pesticide remobilisation in runoff
 - Gradient based exchange between runoff water and a mixing soil layer



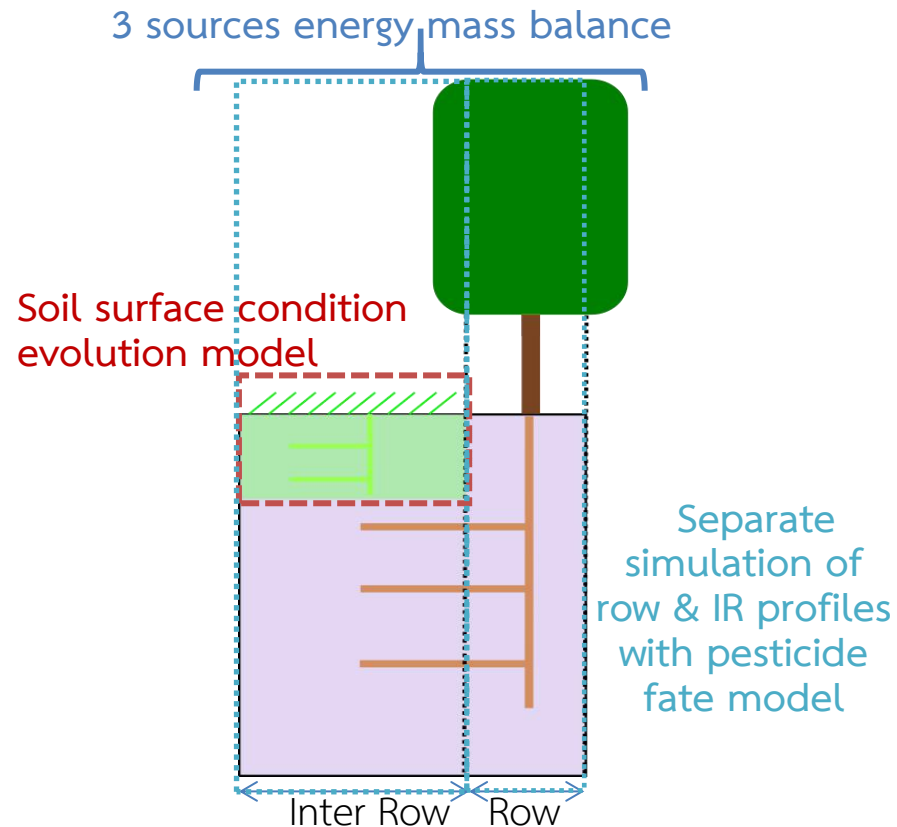
Spatial segmentation of a vineyard plot based on management and overall coupling

- Row / Inter-Row :
 - Distinct evolution of soil surface conditions related to soil management
 - Distinct pesticide applied quantities
 - Distinct rooting patterns related to distinct grass cover

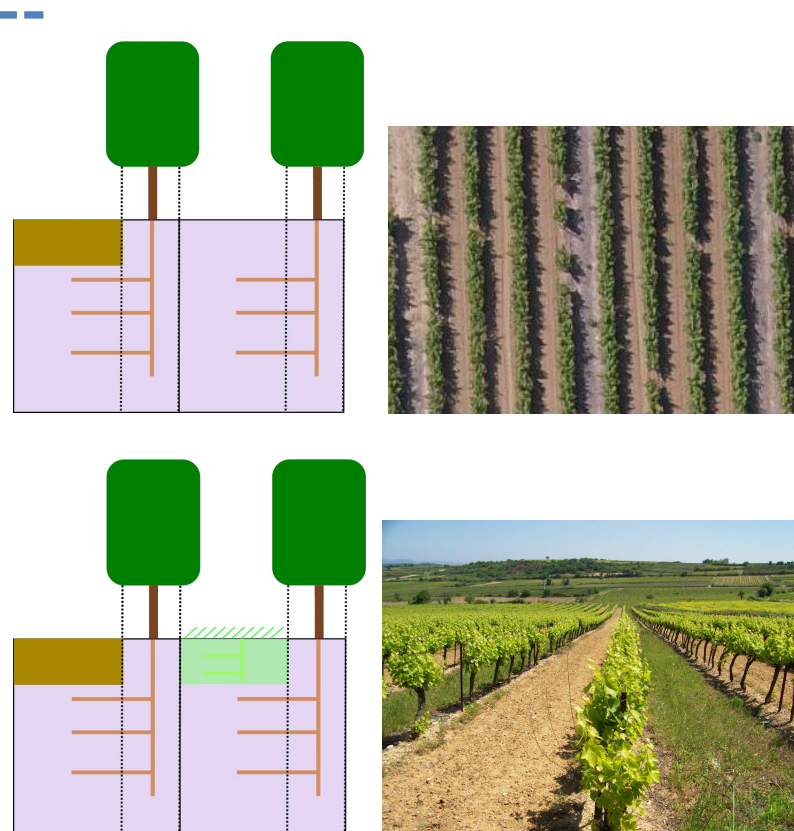
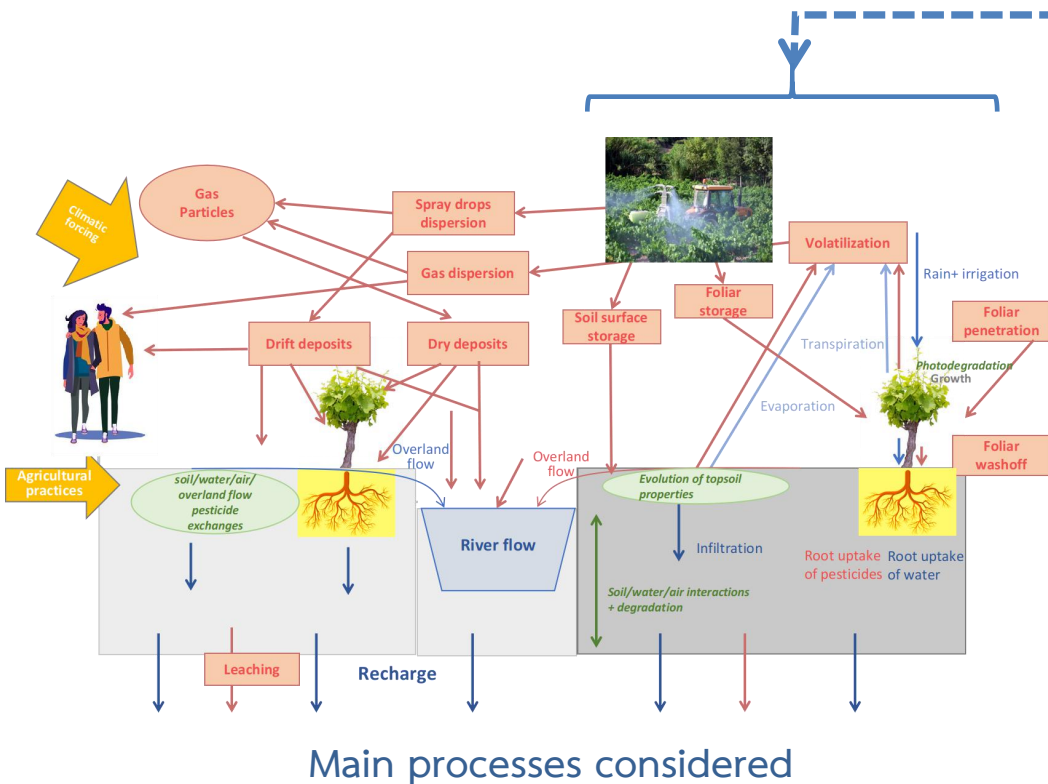


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Integration within the landscape fate model, MIPP model (Voltz et al., 2017)



Model evaluation

- **Ability to reproduce**
 - Volatilization fluxes from vine cover
 - Runoff concentration
- **Model behavior**
 - various soil management operations



Model Evaluation: against volatilization measurements (1/2)

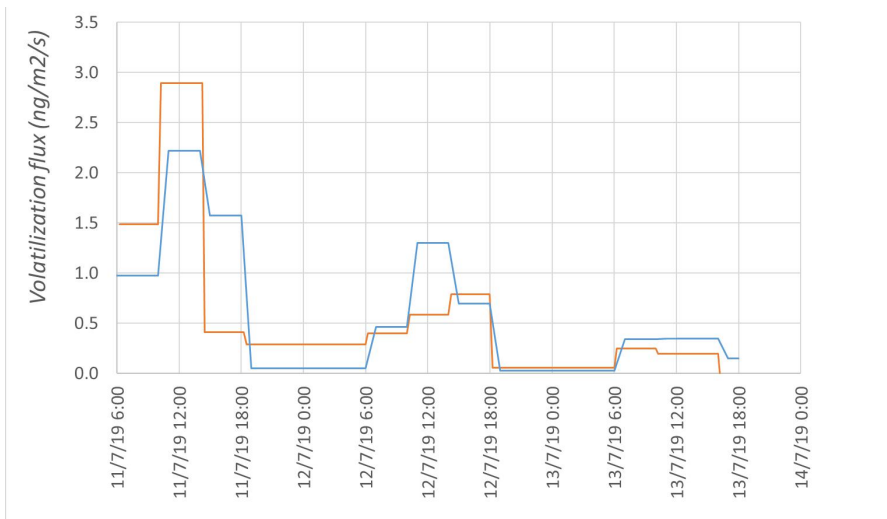
Field experiment in a Mediterranean vineyard

- Application of the fungicide cyflufenamid applied at the recommended dose of 15g/ha on 11 July 2019
- Sprayer : tunnel sprayer
- Measurements during 3 days after application of
 - air temperatures and wind speed profiles at 3 heights
 - air concentrations quantified by TD/GC/MS at 3 heights
 - Standard micrometeorological conditions
- Estimation of volatilization fluxes with the aerodynamic gradient method



Model Evaluation: against volatilization measurements (2/2)

Average **measured** and **simulated** fluxes of cyflufenamid over air sampling periods



Measured losses : 7.9% of applied

Simulated losses : 8.3% of applied

Simulation parameters

Calibrated

- $P_{vap} = 7.5 \cdot 10^{-5}$ Pa
- $\text{Log } K_{ow} = 3.1$
- $K_{oc} = 2.35$ m³/kg
- DT_{50} for leaves = 16h

Fixed

- Soil physical properties

Model behaviour in sum

- Satisfactory overall magnitude and dynamics of fluxes
- Uncertainty on compound behaviour on vine leaves (formulation effect, penetration rate...) → Need of calibration

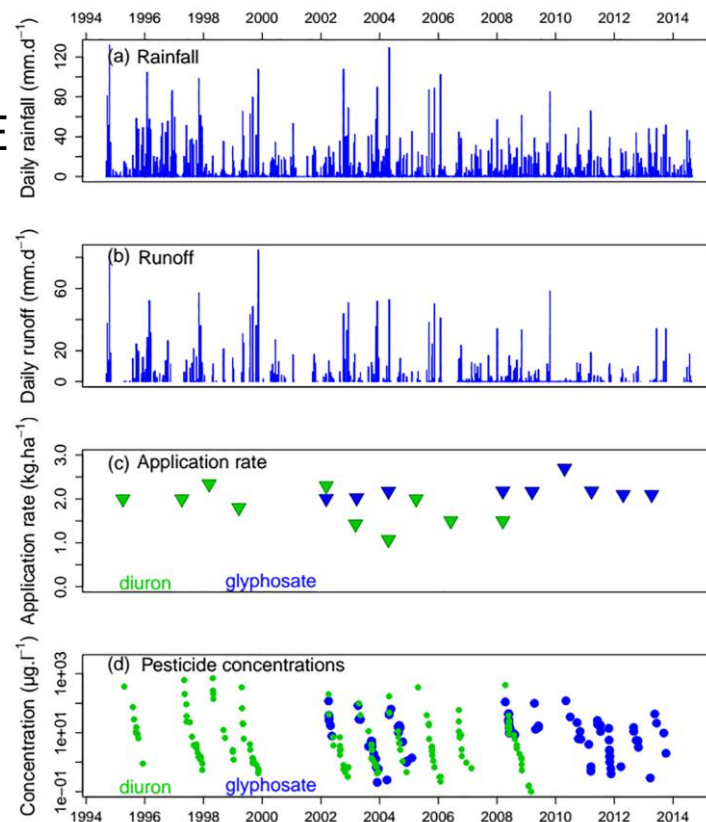


Model Evaluation: against field runoff contamination data (1/2)

Long term field experiment in a Mediterranean vineyard belonging to the Long-term hydrological Observatory OMERE (Molénat et al., 2018)



- Field size : 1200 m²
- Fully chemically weeded, with preemergence (diuron) and/or post-emergence (glyphosate) herbicides
- extensive monitoring from 1995 to 2014
 - Tipping-bucket rainfall data
 - Standard hourly weather data
 - Instantaneous runoff flows
 - Automatic sequential runoff sampling for pesticide residues

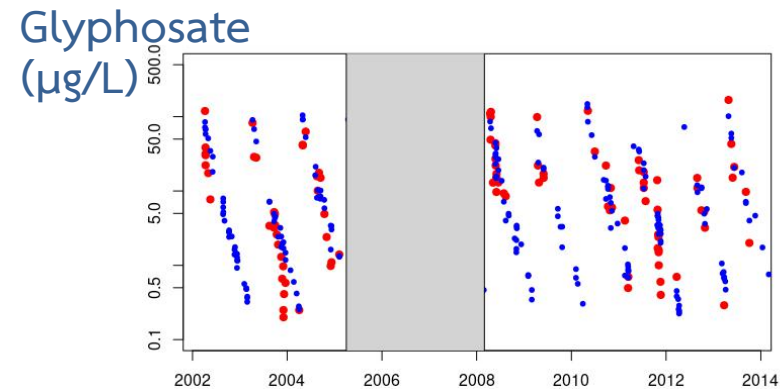
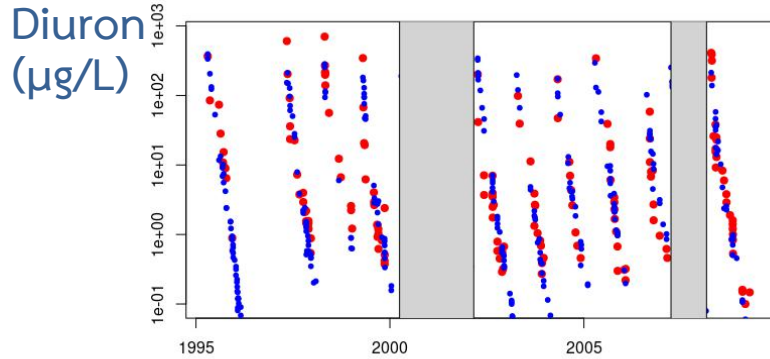


from Métayer et al., (2023)



Model Evaluation: against field runoff contamination data (2/2)

Average **measured** and **simulated** runoff concentration per runoff event



Simulation parameters

- **Calibrated :**

- Diuron Koc 3630 L/kg ; DT50 36 days
- Glyphosate Koc 17150 L/kg ; DT50 52 days

- **Fixed**

- Mixing depth
- Soil-runoff water exchange coefficient

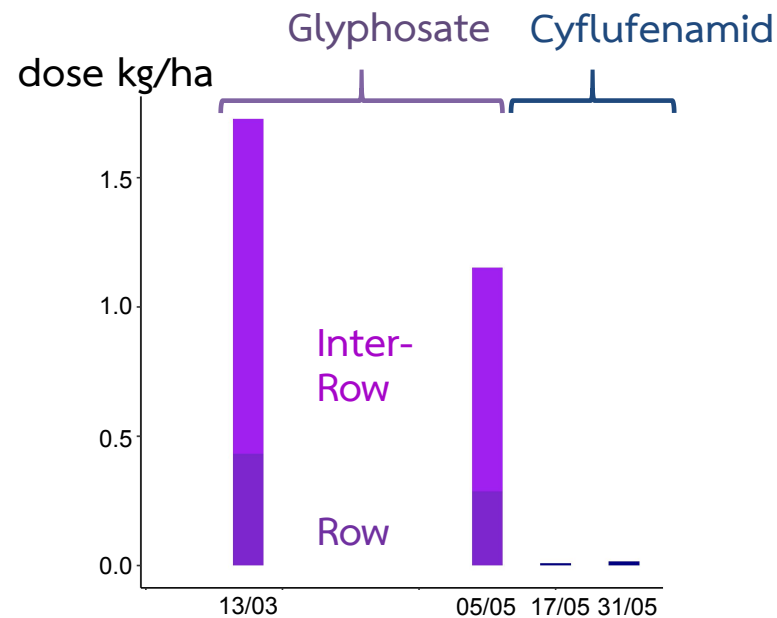
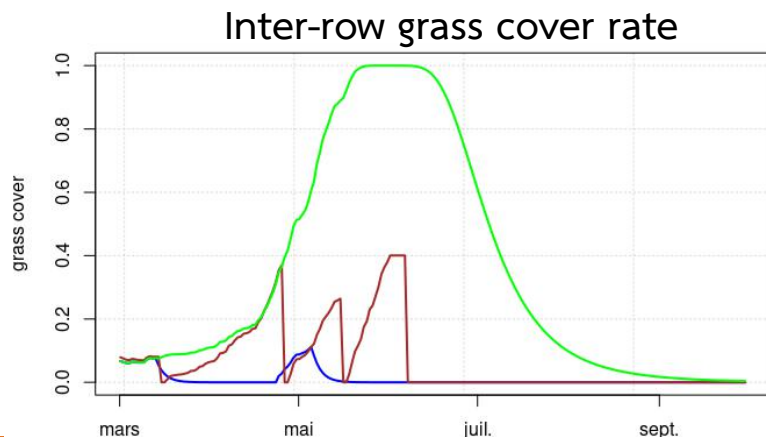
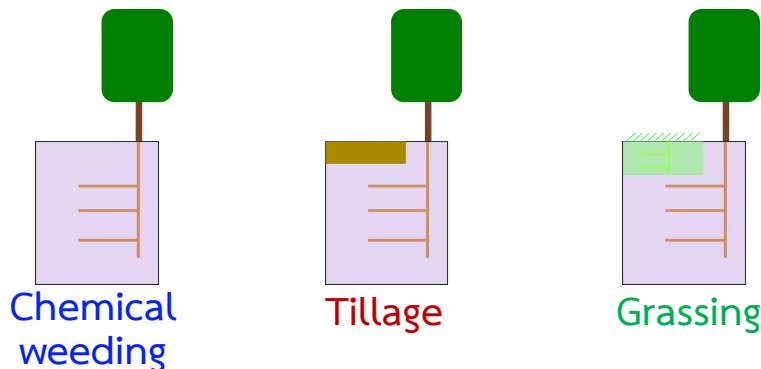
Model behaviour in sum

- Good order of magnitude of simulated runoff concentrations and intra-annual & pluri-annual trends
- Difficulties to simulate small events (low rainfall intensities)



Model behavior : pesticide fate for 3 soil treatment practices (1/3)

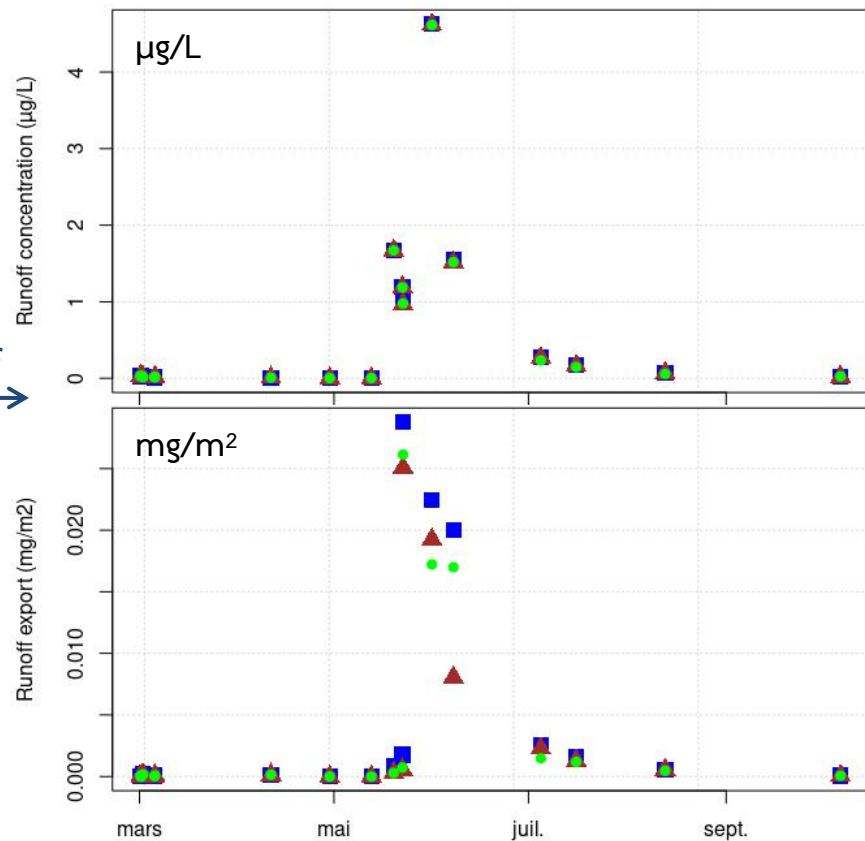
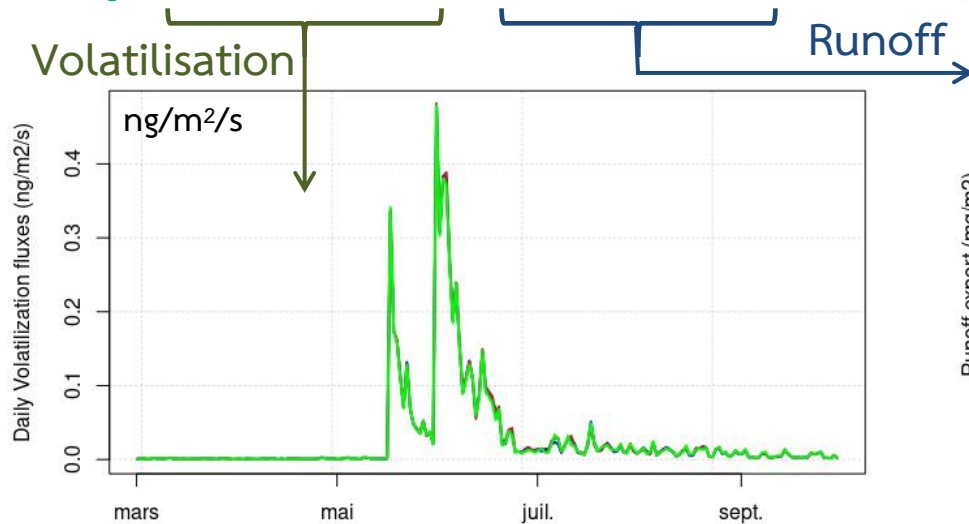
Comparison of 3 Inter-Row weed control practices :



Model behavior : pesticide fate for 3 soil treatment practices (2/3)

Cyflufenamid :

	$\mu\text{g}/\text{m}^2$	% applied	$\mu\text{g}/\text{m}^2$	% applied
Chemical weeding	531	21.47	79.04	3.19
Tillage	538	21.75	57.88	2.34
Grassing	527	21.3	65.02	2.63



Model behavior : pesticide fate for 3 soil treatment practices (3/3)

Glyphosate :

$\mu\text{g}/\text{m}^2$ % applied $\mu\text{g}/\text{m}^2$ % applied

Chemical weeding

$2\text{e-}4$ - 2371 1.10

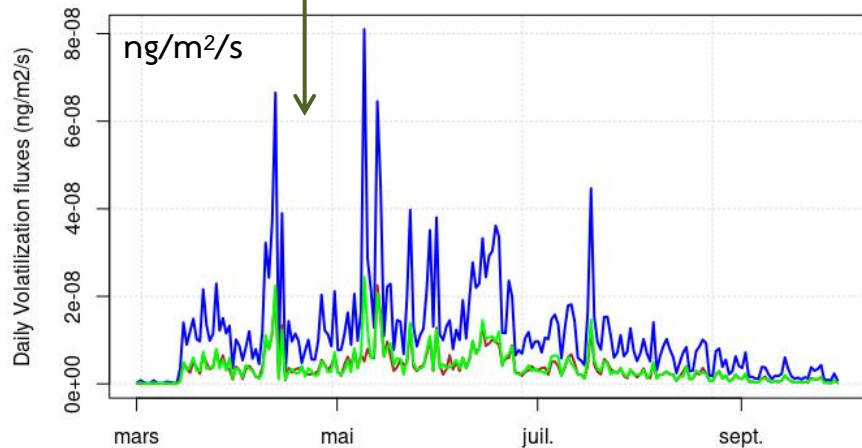
Tillage

$7\text{e-}5$ - 784 1.09

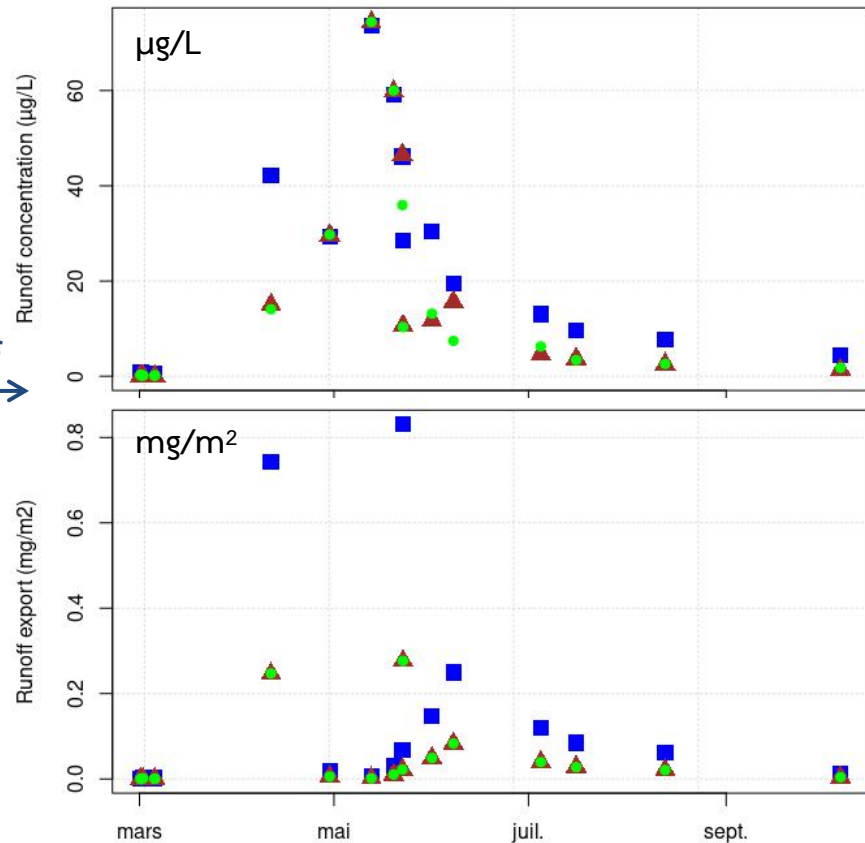
Grassing

$7\text{e-}5$ - 787 1.09

Volatilisation



Runoff



Concluding remarks and next steps

- **Original plot-scale modeling of pesticide fate**
 - in soil, water and air
 - adapted to main vineyard heterogeneities
 - but row/inter-row connections to be improved
 - integrated within the MIPP landscape model
- **First evaluations**
 - are encouraging on volatilization and runoff contamination
 - show that calibration is needed
 - must be supplemented by further multi-compartment and multi-molecules evaluations
- **Actual and future use**
 - To assess environmental impacts of farmed practices at the plot and landscape scale (Voltz et al. this conf) and more generally to contribute to pesticide risk evaluation in the framework of the OneHealth approach



Thank you for your attention

and special thanks to all participants to the experiments :
Brigitte Durand, Céline Décuq, Baptiste Esnault and the OMERE ORE team

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