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

Simulating pesticide fate in row-planted plots using the MIPP model (OpenFLUID x VSoil) – Application for evaluating strategies to reduce pesticide use in southern viticulture.

C. Dagès[1], D. Crevoisier[1], C. Bedos[2], F. Lafolie[3], E. Personne[2], N. Beudez[3], M. Faucher[1], J.-C. Fabre[1], A. Thoni[1], F. Vinatier[1], M. Voltz[1]

1- INRAE Montpellier

2- INRAE Paris-Saclay

3- INRAE Avignon

VSoil meetings 26-27 March 2026

Heterogeneities in vine plots enhaced by farm practices

Various soil management practices and pattern



heterogeneity on
transfer & retention
soil properties

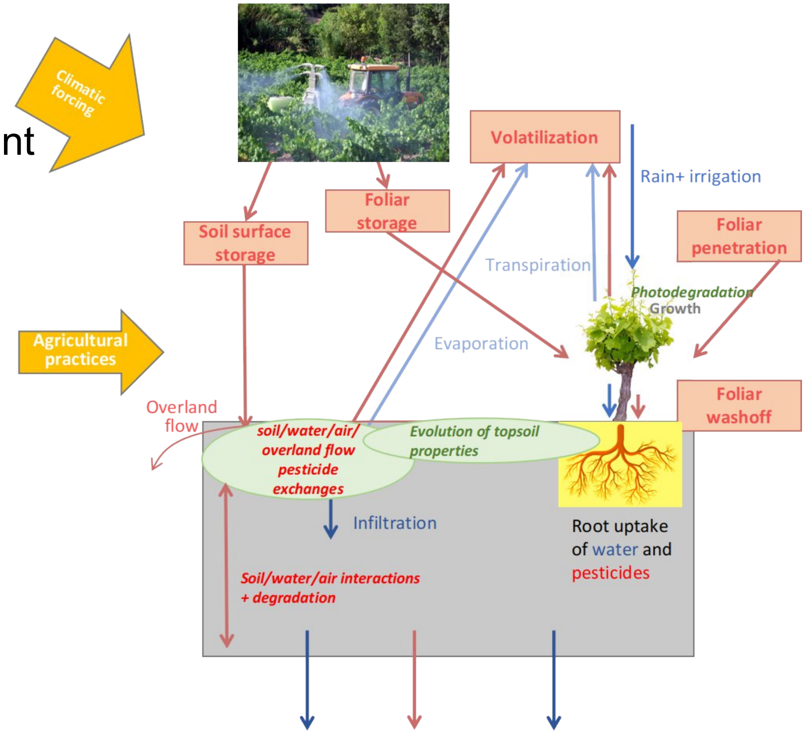
Sprayers and Pesticide distribution



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
    - Mechanistics pesticide fate model in Soil-Plant continuum
  - **Spatial segmentation adapted**
    - Row and Inter-Row (IR) differences
    - Process resolution needs

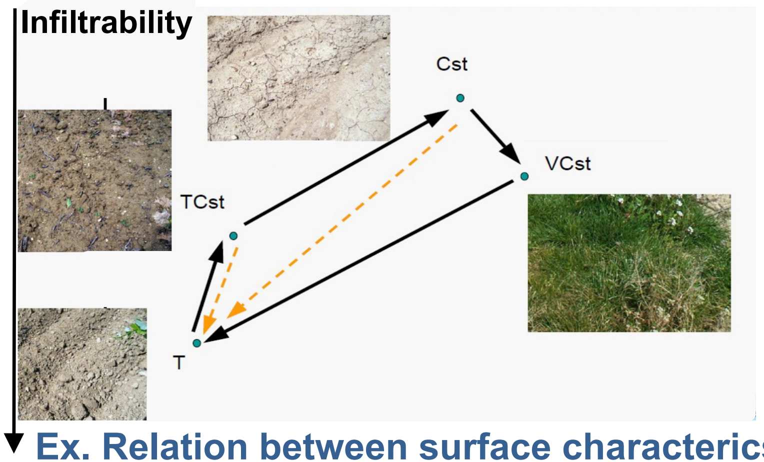


Main processes considered

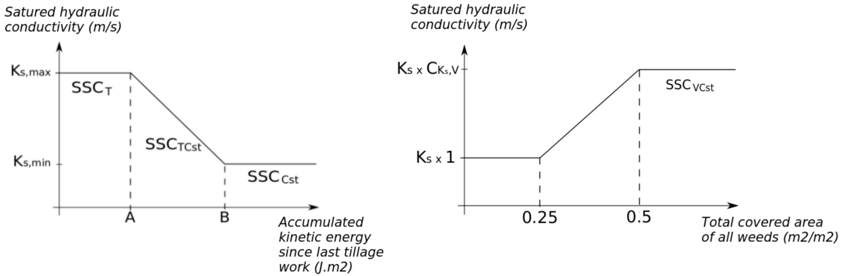
Changes in soil surface conditions due to soil treatment practices and grass growth

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 rainfal kinetic energy
    - Relationship between soil hydraulic conductivity and grass cover and crust cover



Ex. Relation between surface characterics and infiltrability

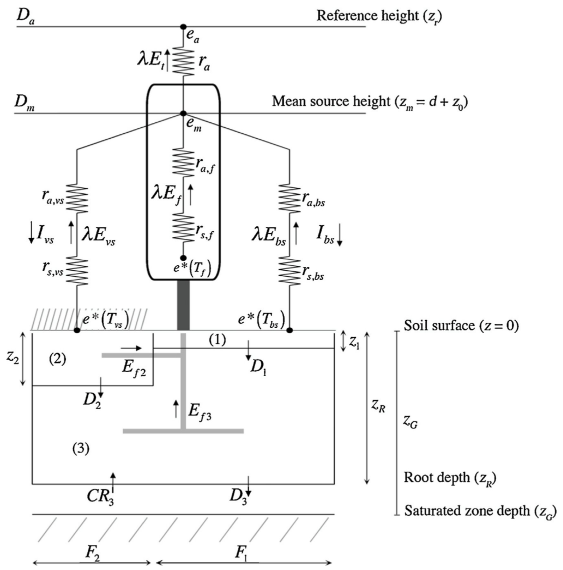


Evolution of hydraulic conductivity

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



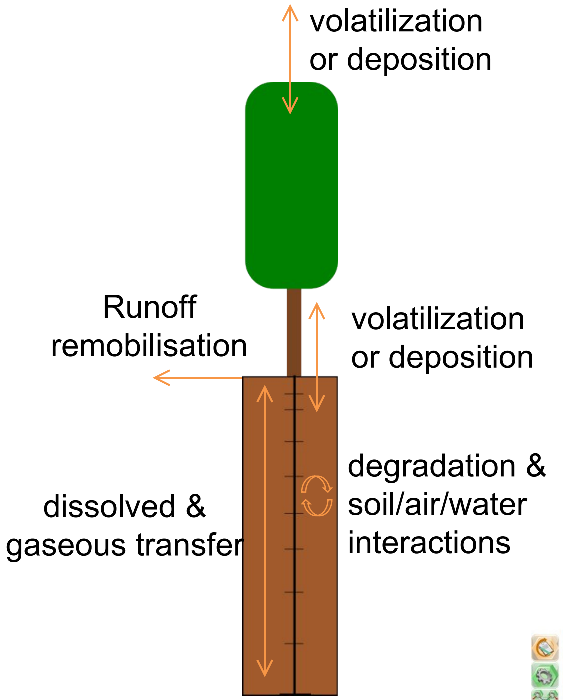
Schematic representation of the three source energy balance model

(in Montès et al., 2014)

Mechanistics pesticide fate model in the soil-plant system

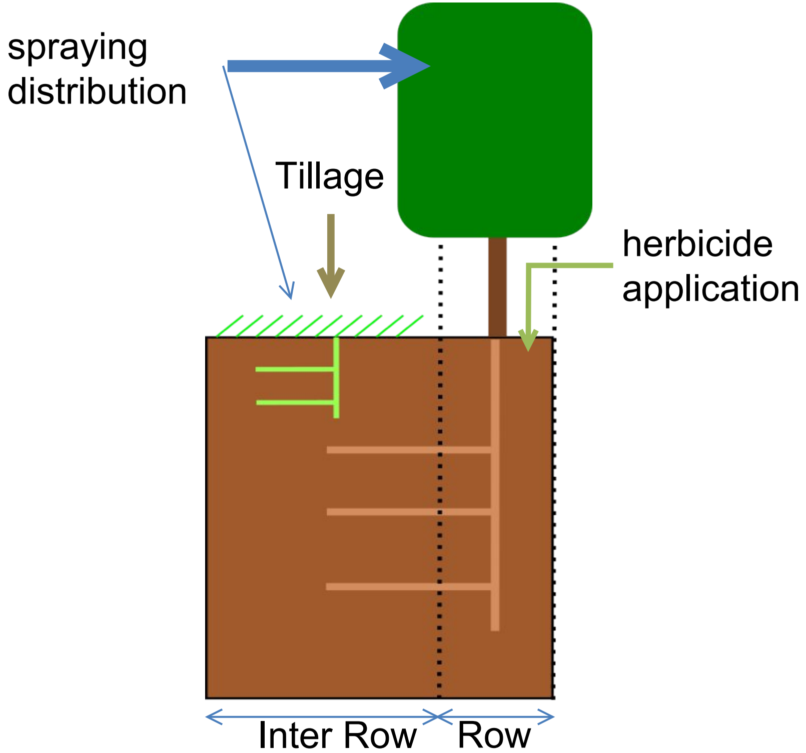
Based on the coupling of Pastis (Lafolie et al. 1991) and Volt'air (Bedos et al., 2009):

- 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 compartimental 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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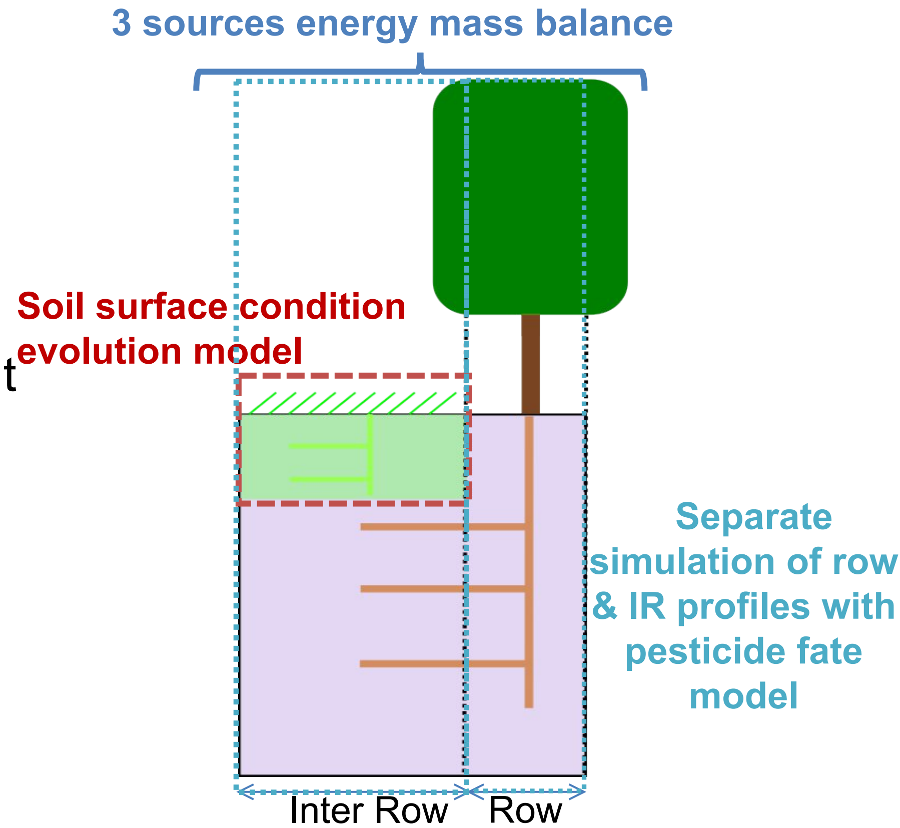
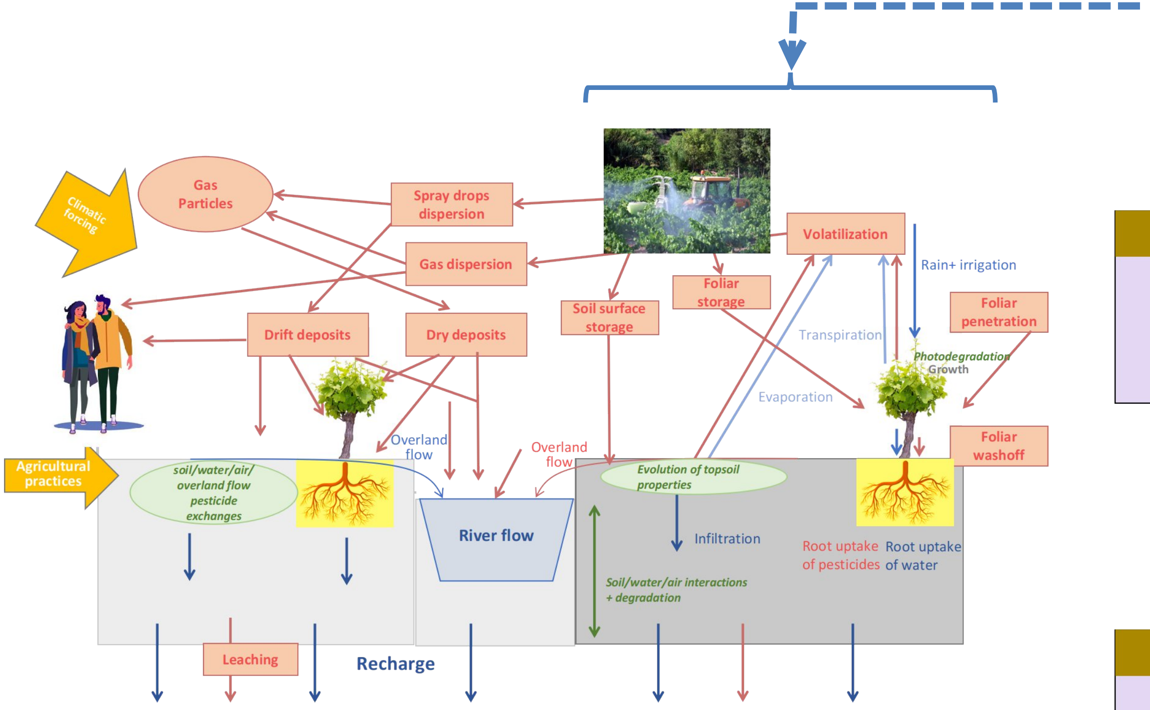
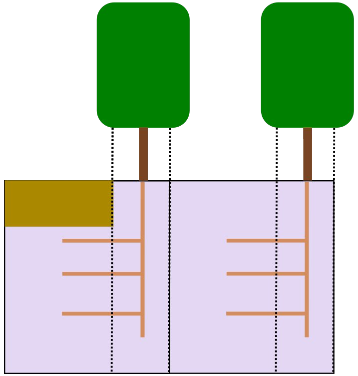
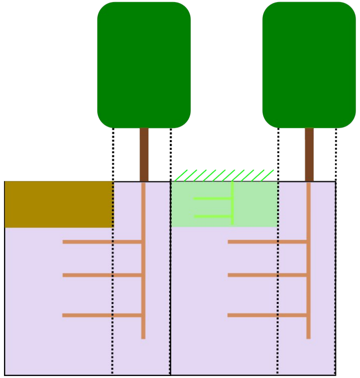


Integration within the landscape fate model, MIPP model (Voltz et al., 2017)

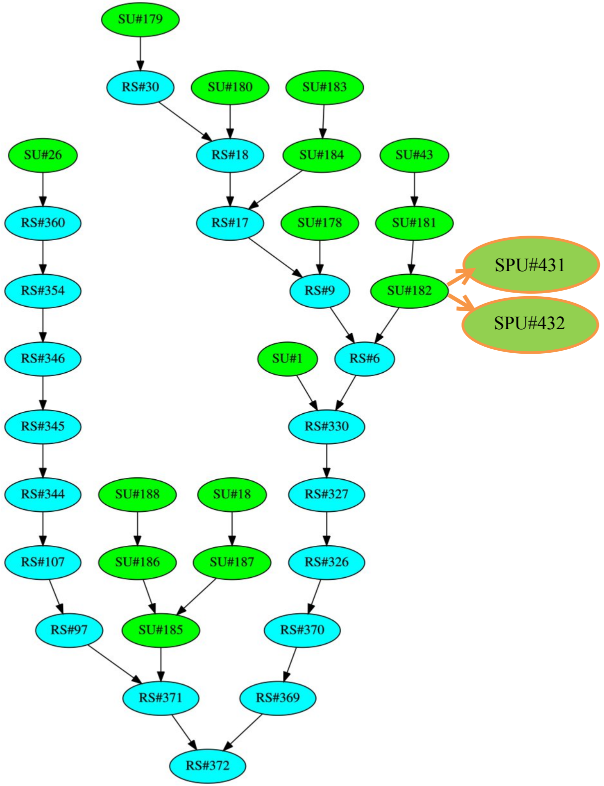


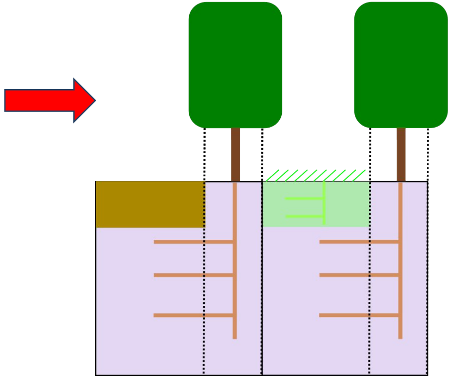
Main processes considered





Spatial representation at the landscape scale (1/2)

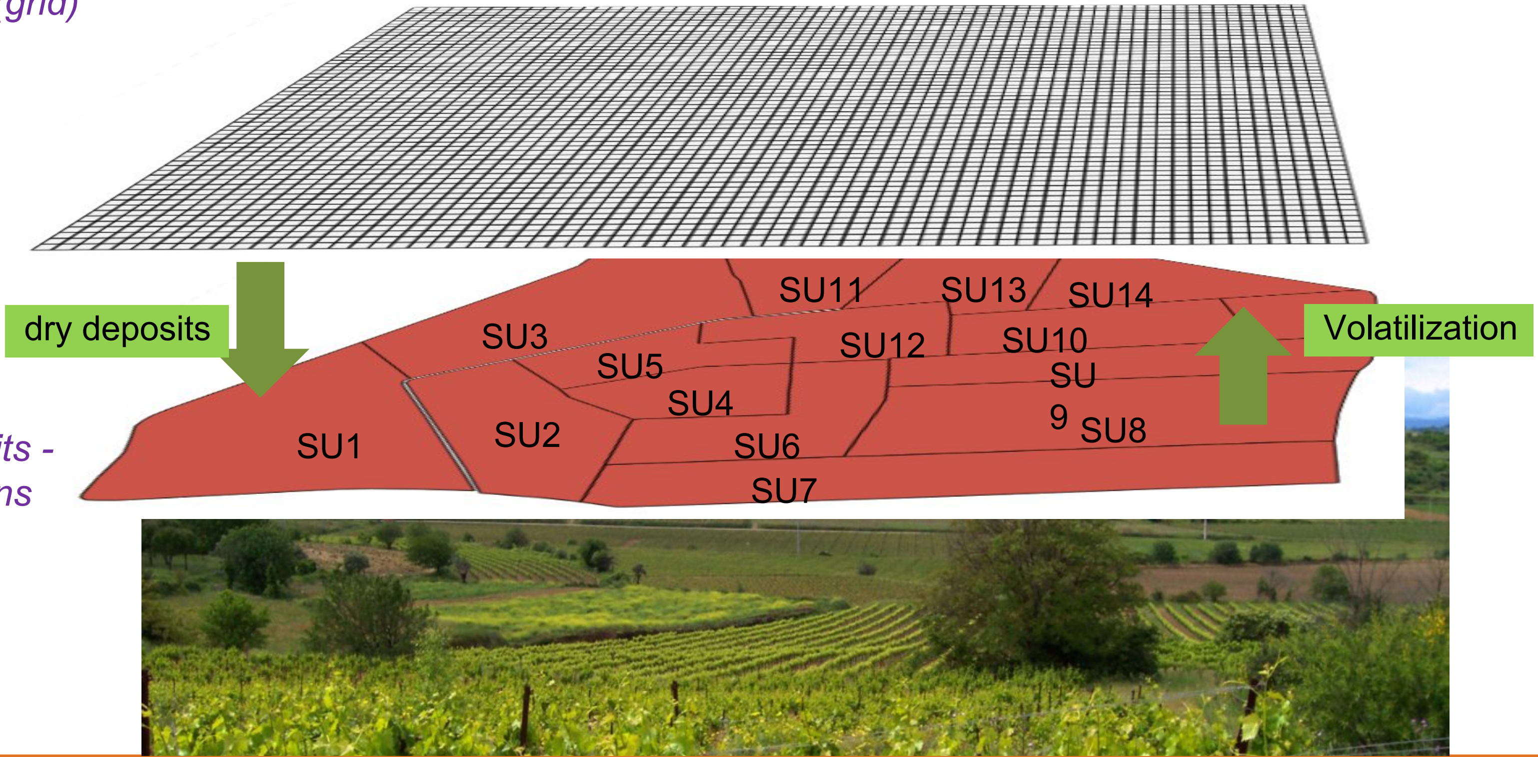




OpenFLUID
Software Environment
for Spatial Modelling in Landscapes

Spatial representation at the landscape scale (2/2)

Atmospheric units - regular mesh (grid)



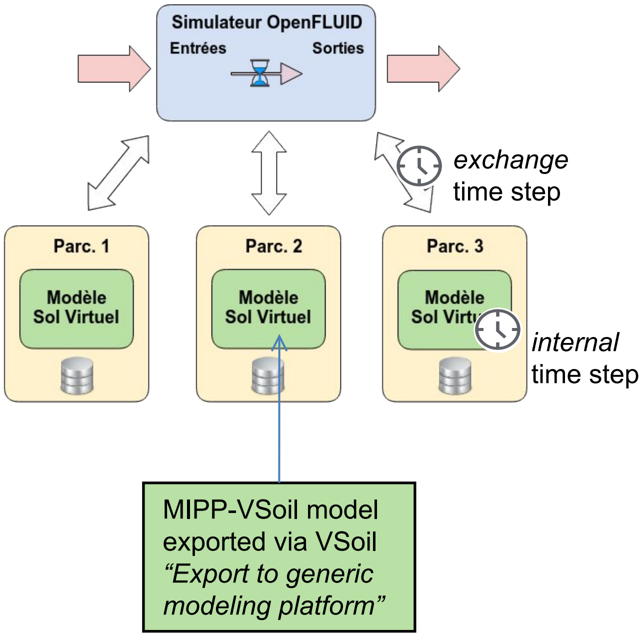
Field units - polygons

MIPP from an engineering perspective...

- 2 modelling frameworks
  - OpenFLUID
    - master for its landscape representation abilities
    - availability of hydrological modules for water and solutes (surface lateral transfers)
  - VSoil
    - availability of a coherent set of modules for 1-D multi-phase transport in soil for water and solutes

- Interoperability
  - via blocking asynchronous messages (0mq)
    - exchanged between an OpenFLUID *interfacing* simulator and the MIPP-VSoil model,
    - messages containts
      - input variables for MIPP-VSoil model (from OF-modules)
      - output variables of MIPP-VSoil model (to OF-modules)
  - OF operates :
    - run of N independant MIPP-VSoil models
    - constraint MIPP-VSoil time step for message exchanges

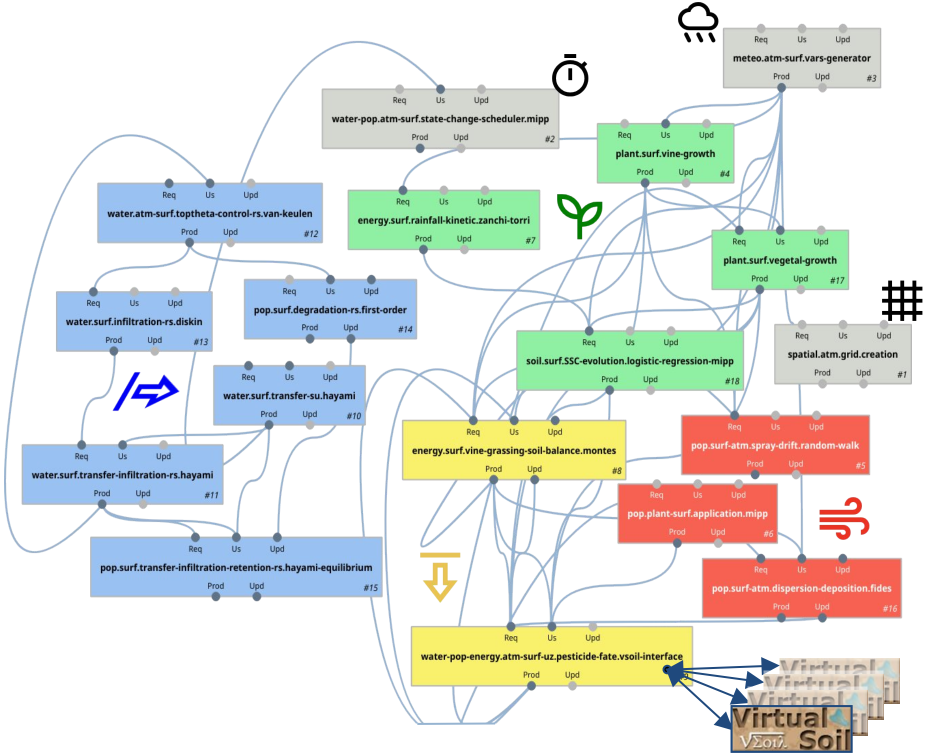
VSoil : lancement de N instances



Model composition and Coupling scheme

- 18 OF- modules:
  - water&pesticides surface transfers
  - water&pesticides transfers in the soil-plant system
  - vegetation growth and soil surface condition evolution
  - spray drift, deposition and atmospheric dispersion
  - climatic forcing
  - soil-atmosphere exchange control

- Type of coupling
  - variable exchanges
  - ~ sequential
- Time steps
  - module time steps depending on the processes (from 1s to 1 day)
  - variables exchanges time step
    - 5 or 30 min. depending on weather conditions



MIPP coupling scheme

Overview of MIPP-VSoil model

- soil_for_MIPP
  - documentation generation
  - source code generation
  - platform Fortran source code
  - time_forced_MIPP
  - surf_energy_balance_forced_MIPP
  - atm_gas_conditions_forced_MIPP
  - climate_forced_MIPP
  - crop_dev_forced_MIPP
  - phyto_appli_forced_MIPP
  - bottom_temp_forced_MIPP
  - soil_tillage_prac_forced_MIPP
  - upstream_runoff_forced_MIPP
  - soil_structure_forced
  - no_sprink
  - bottom_gas_conditions_forced_MIPP
  - no_mulch_dynamics
  - bottom_solutes_conc_forced
  - no_mineral_fertilisation
  - bottom_heat_flux_forced
  - surface_pressure_forced
  - flood_irrigation_forced
  - pref_flow_neutral
  - bottom_water_flux_forced
  - bottom_pressure_forced
  - mulch_leaching_neutral
  - canopy_water_transfer_neutral
  - Canopy_Pest_Fate_MIPP
  - hydraulic_properties_francois_MIPP
  - mulch_water_neutral
  - rw_uptake_alpha_asso_crops
  - Richards_KDW_MIPP
  - runoff_MIPP
  - heat_Pastis_MIPP
  - phy_chem_MIPP
  - CDE_MIPP
  - gas_Fick_oldh_MIPP
  - platform C++ source code
  - coupler source code
  - executable generation
  - Singularity cache cleaning

Model Application

- **Ability to reproduce environmental fluxes**

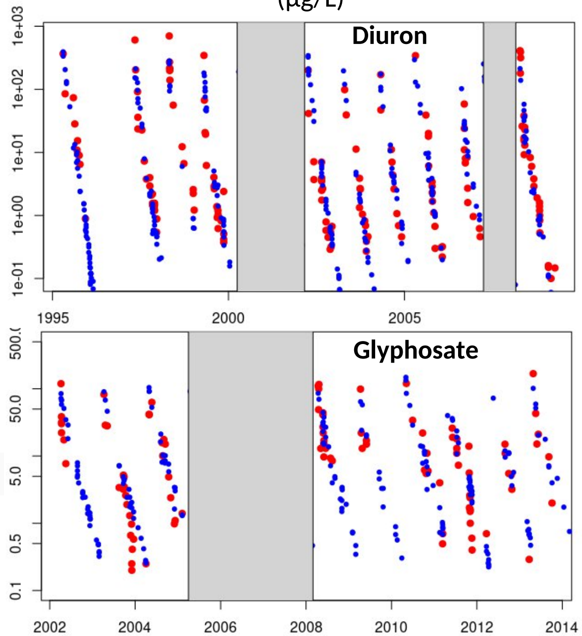
- **To evaluate vine growing strategies**
  - the RIPP project

Model Evaluation (ongoing work)

against data from long term observatory (ORE OMERE) and side experiments

- **20 years of field runoff concentration**

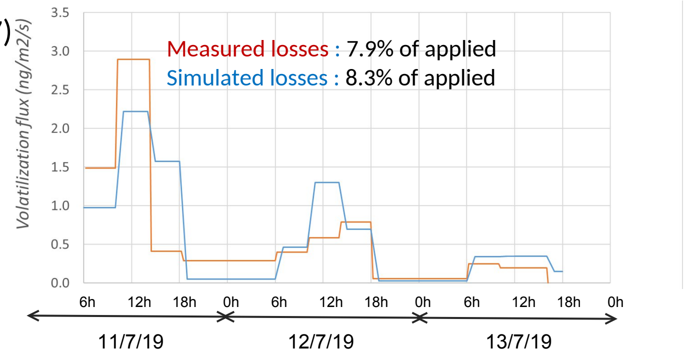
Average measured and simulated runoff concentration of pesticide per runoff event (µg/L)



(Molénat et al., 2017)

- **3 days of volatilization measurements** (Bedos et al.)

Average measured and simulated fluxes of cyflufenamid over air sampling periods



- **3 months of actual soil evaporation vine transpiration measurements** (from Trambouze et al., 1996)

AAP ECOPHYTO

« Leviers territoriaux pour réduire l'utilisation et les risques liés aux produits phytopharmaceutiques » 2020-2023

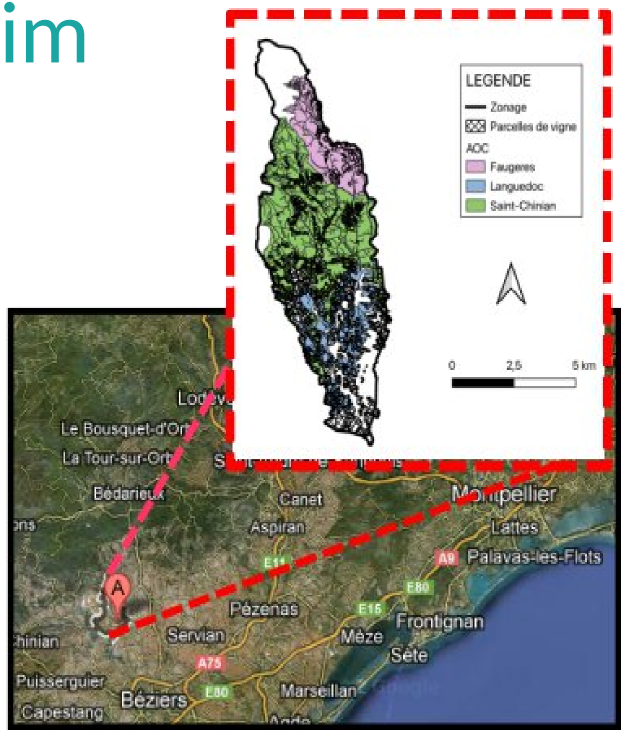
RIPP-viti ECOPHYTO project :
A participative and holistic approach to build sustainable vineyard management strategies and assess their environmental impacts

Context and Aim

- French national environmental road map :
  - 50% decrease in synthetic pesticide use by 2025 2030 (Ecophyto Plan)
- Vineyard areas in France are particularly at stake
  - ≈ 3.0% of French agricultural area but 20 % of pesticide use
  - the network of DEPHY Farms demonstrates the efficacy of a number of levers to decrease pesticide use (Fouillet et al., 2023)

Aim

Develop and evaluate sustainable strategies to reduce the use of pesticides and their impact on air, water, and soil quality at the scale of a wine-growing landscape

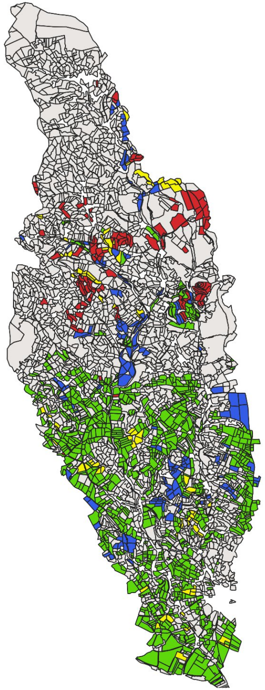


the Rieutord catchment in south France :

- **45** km^2 of which 15 km^2 are vineyards
- a drinking water supply markedly polluted by herbicides used in vineyards

Project approach

1- initial diagnosis



farms types distribution

2- participatory approach: playing a serious game for designing new management strategies (Hossard et al., 2021)

- depending on farm type, soil, distance to houses
- ex of levers : foongicie protection; soil management practices

3- Using simulation to evaluate strategies impact

- **social and economity sustainability** (with DexiPM Vigne)
- **environmental** (with MIPP)
  - drinking water
  - soil organisms
  - aquatic organisms
  - bystanders

Project approach

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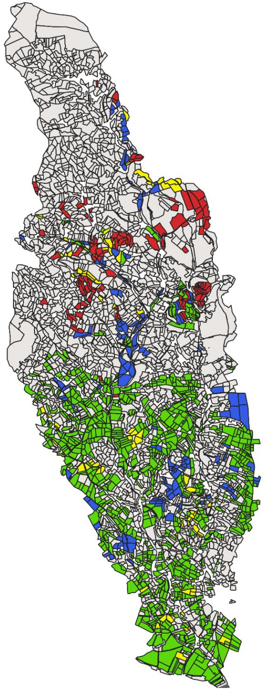

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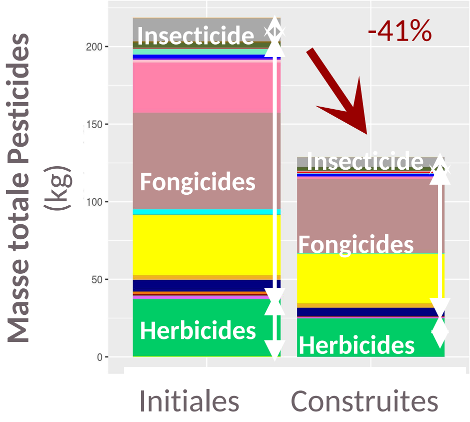

~30 strategies

3- Using simulation to evaluate strategies impact

- **social and economity sustainability** (with DexiPM Vigne)
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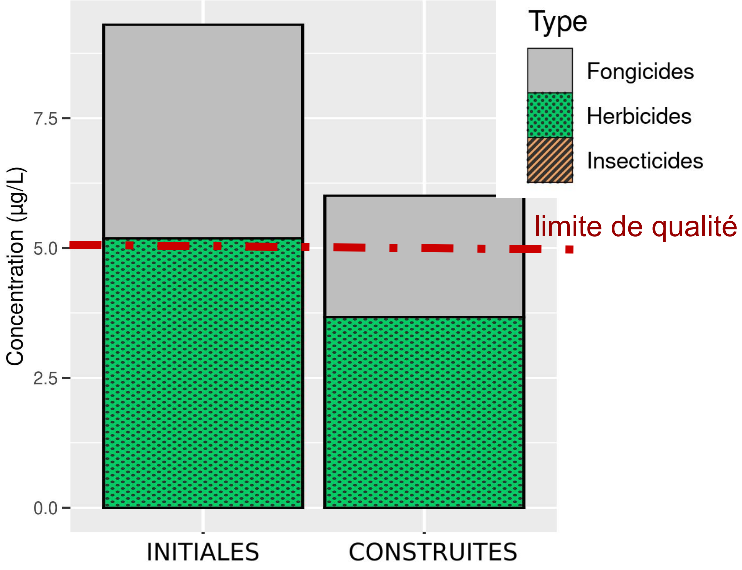
Impact reduction with new strategies

Concentrations annuelles moyennes sur 20 ans des eaux de ruissellement des versants



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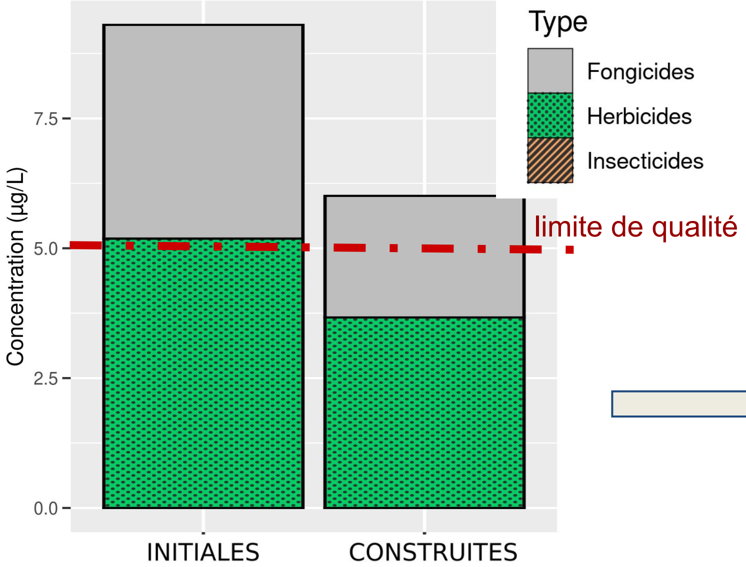

Risque d'impact

	Etat initial	Stratégies de réduction des usages	Principales molécules impactantes
Organismes du sol			fongicides (non CMR)
Organismes aquatiques			fongicides & insecticide
Eau potable			herbicide
Riverains		à	fongicides CMR

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
  - 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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ÉCOPHYTO
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