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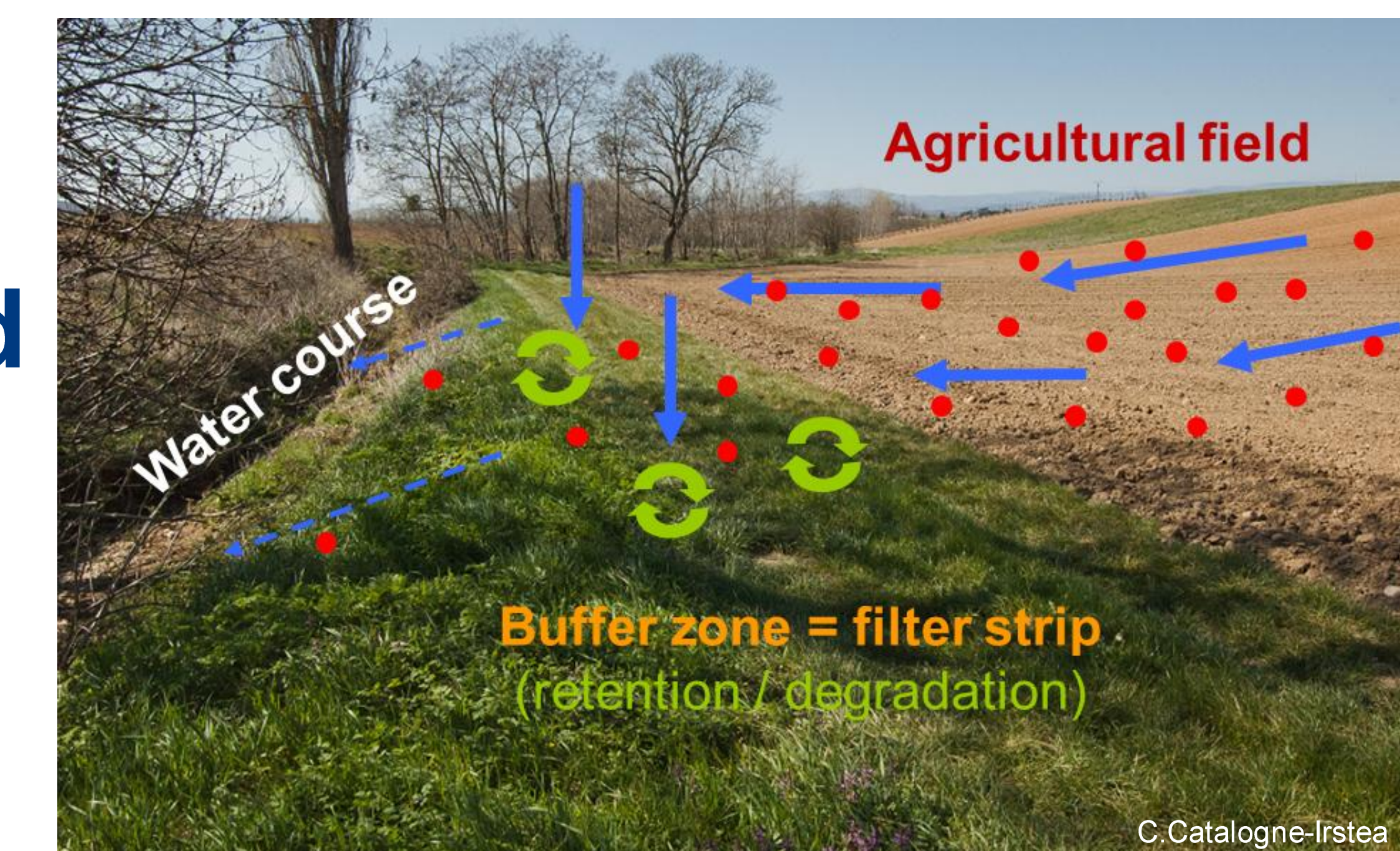
# Kriging-based metamodelling with qualitative variables to design grassed buffer zones in small agricultural catchment

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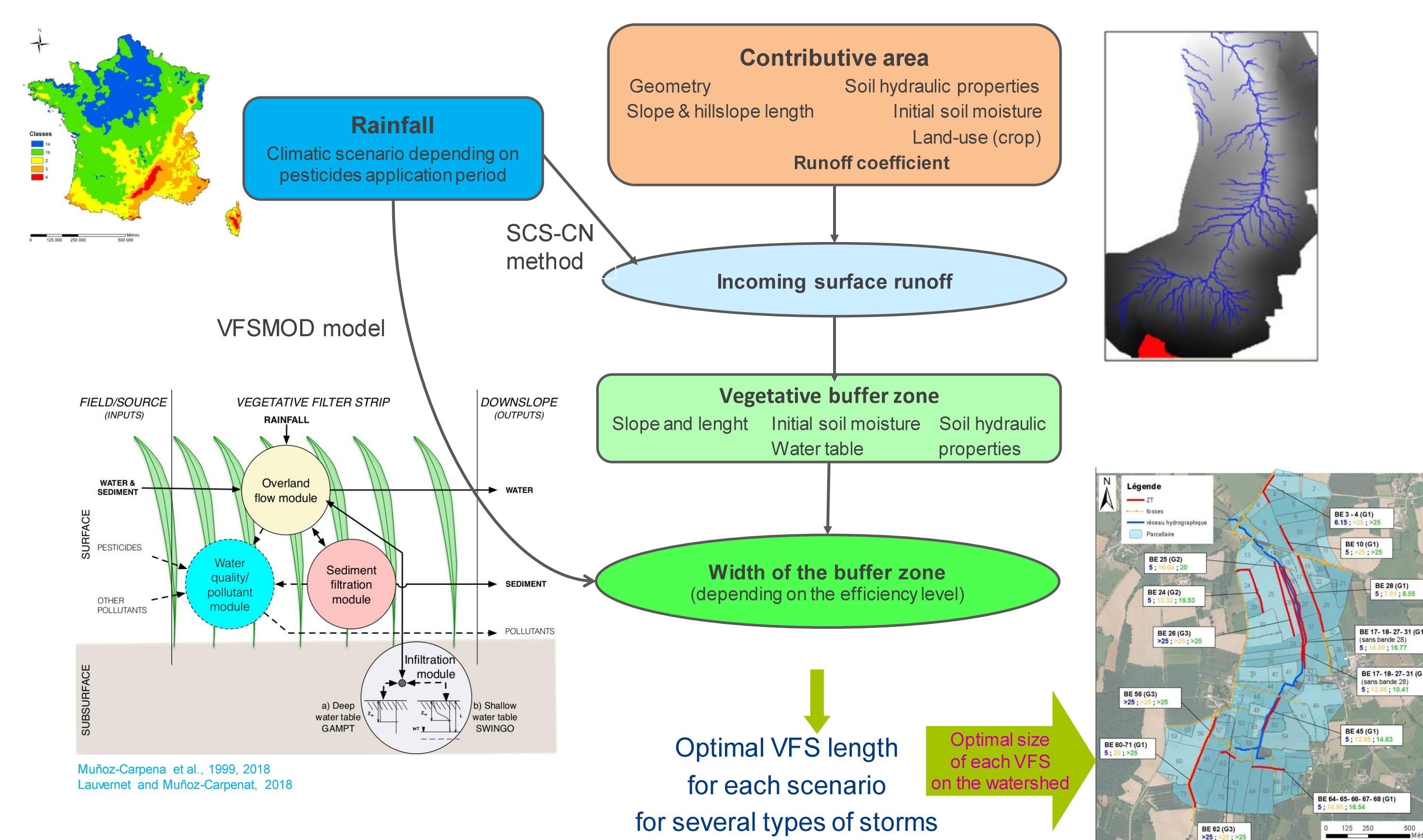
## Objectives

- Buffer strips are identified as the BMP of Choice for Runoff Mitigation to limit contamination of surface water by pesticides.
- Their efficiency strongly depends on soil, agronomic and climatic conditions and they need to be optimized by considering appropriate sizing.
- Irstea developed a complete/complex toolkit to design site-specific VFS by simulating their efficiency to limit runoff transfers : BUVARD (Carlier et al., 2017).
- This tool is based on quantitative *and* qualitative variables
- Need for a simpler and efficient tool for end-users
- A metamodel of BUVARD = methodological challenges for operational purposes

## The toolkit BUVARD\*

BUffer strip for runoff Attenuation and pesticides Retention Design tool

**Hypothesis** : buffer zone efficiency = ability to retain surface runoff

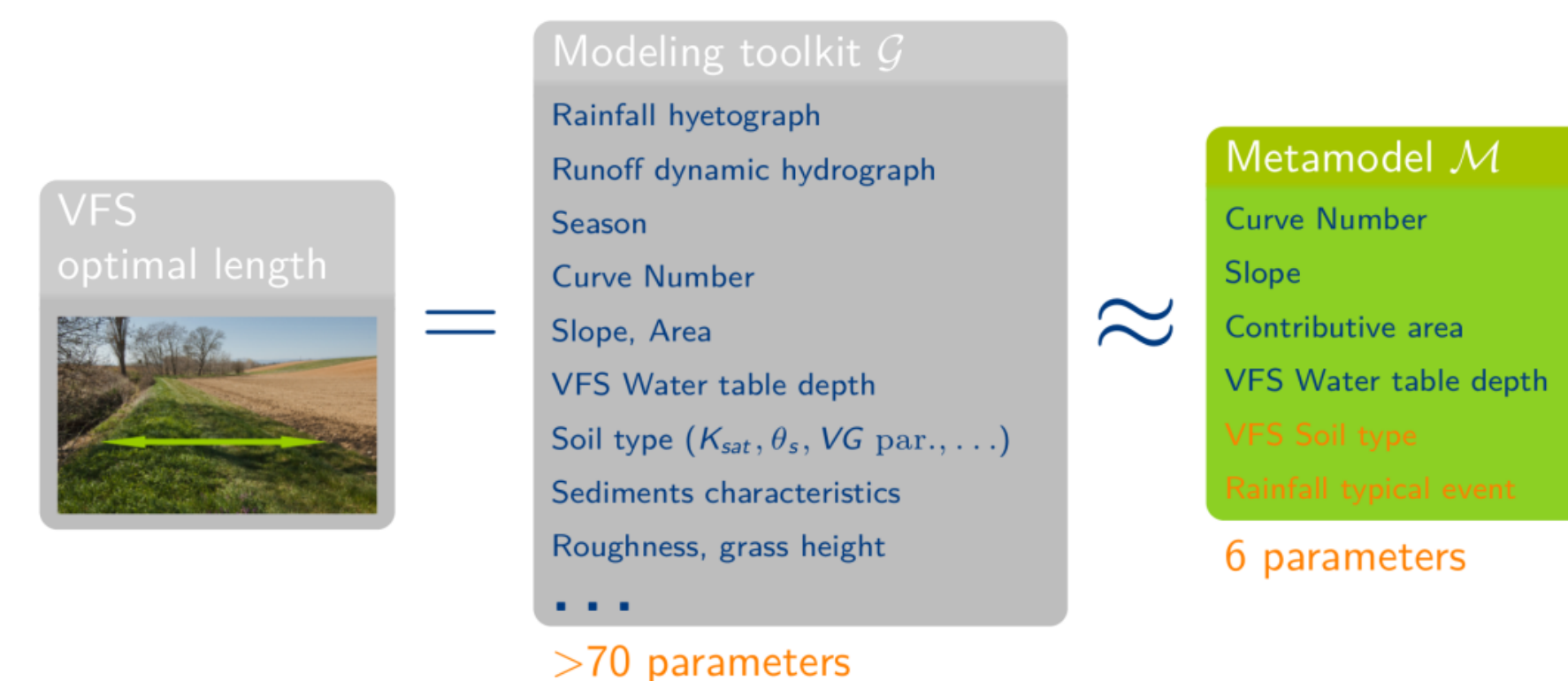


\* <http://buvard.irstea.fr/>

## Methods for building the metamodel

### Why metamodelling BUVARD?

- Simple to use but still based on physics
- Able to evaluate an output of the toolchain at any point of the domain
- Allows evaluating sensitivity indices at smaller numerical cost
- Can be easily coupled/integrated in hydrological modeling frameworks



**BUT: How to deal with qualitative/categorical variables (type of soil, type of rainfall event), that are typical in water quality modeling?**

### Stochastic method ?

#### Gaussian Processes / Kriging

The relation between points is expressed by a covariance structure between the obs.

→ Need for an adapted cov. kernel

### Deterministic method ?

#### GAM (Generalized Additive Model)

The relation between points is assumed to be deterministic and explicit

→ Ok with qualit. var.

### Gaussian Processes with mixed variables:

- Hyp. = the deterministic output of the model is the realization of a GP
- The GP Z is conditioned by points from the model simulations (still a GP)
- Several options to deal with categ. var.:
  - one GP per modalities couple
  - adapting the covariance kernel by progressive complexity

$$Z(x) = m(x) + W(x)$$

$$\text{Cov}(W(x), W(x')) = c(x, x') = \sigma^2 R(\theta, x, x')$$

$$R(\theta, x, x') = \prod R_k(\theta_k, x_k, x'_k)$$

$$R(\theta, x, x') = \prod_{j=1}^J \tau_j \prod_{k=1}^K R_k(\theta_k, x_k, x'_k)$$

corr. fun. of quali factor j  
 $\tau_{j, z_{ij}, z_{hj}} = \rho_{ij} \rho_{hj} \mathbb{1}[z_{ij} \neq z_{hj}]$

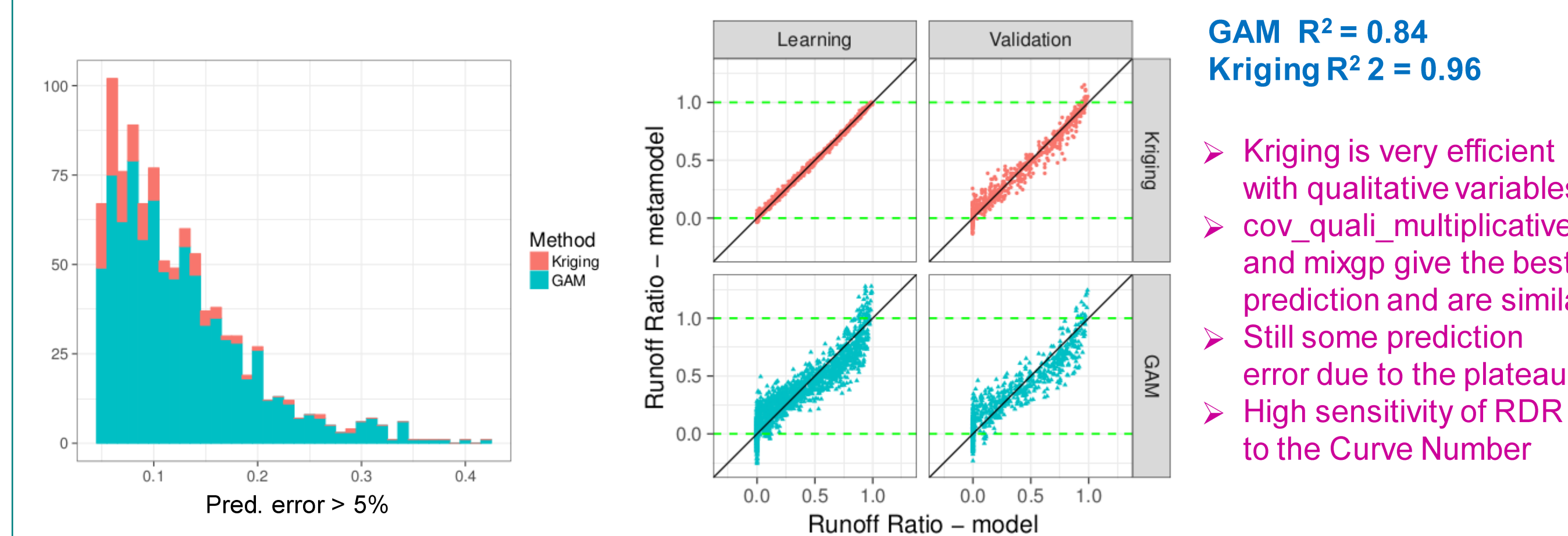
corr. fun. of quanti. factor  
 $c(x - x') = \sigma^2 \exp\left(-\frac{(x - x')^2}{\theta}\right)$

Kernel	6 modalities for soil type:	4 modalities for rainfall:	Total
cov-quali-isotropic	$\begin{pmatrix} 1 & \rho & \rho & \rho \\ & 1 & \rho & \rho \\ & & 1 & \rho \\ & & & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & \mu & \mu & \mu \\ & 1 & \mu & \mu \\ & & 1 & \mu \\ & & & 1 \end{pmatrix}$	2
cov-quali-multiplicative	$\begin{pmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} \\ & 1 & \rho_{23} & \rho_{24} \\ & & 1 & \rho_{34} \\ & & & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & \mu_1 \mu_2 & \mu_1 \mu_3 & \mu_1 \mu_4 \\ & 1 & \mu_2 \mu_3 & \mu_2 \mu_4 \\ & & 1 & \mu_3 \mu_4 \\ & & & 1 \end{pmatrix}$	10
mixgp	$\begin{pmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} \\ & 1 & \rho_{23} & \rho_{24} \\ & & 1 & \rho_{34} \\ & & & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & \mu_{12} & \mu_{13} & \mu_{14} \\ & 1 & \mu_{23} & \mu_{24} \\ & & 1 & \mu_{34} \\ & & & 1 \end{pmatrix}$	21

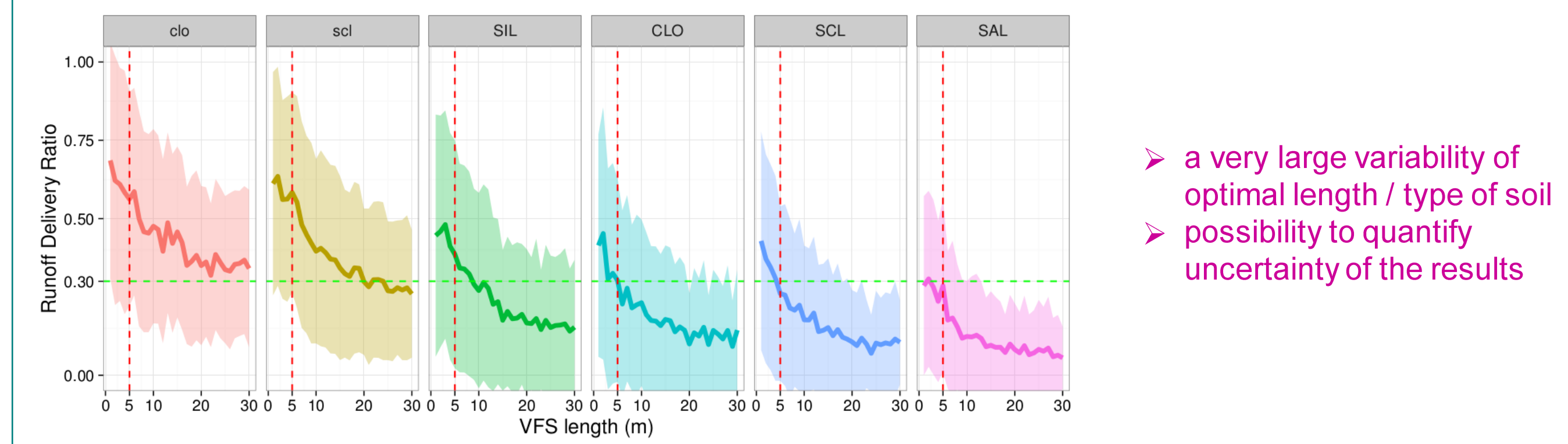
## Results

- Comparison of two methods : Kriging & Generalized Additive Model
- Kriging was adapted to qualitative variables with adapted covariance model

Output variable is the Runoff Delivery Ratio  $\bar{R} = \text{Runout}/\text{Runin}$  :  
 RDR = 0 efficiency = 100%; RDR = 1 efficiency = 0%



- Uncertainty analysis : Average efficiency and uncertainty on large sample simulations (24 000)



## Conclusion

- Qualitative variables were properly taken into account by the GP adaptation
  - Good quality of prediction (94 % of variance) but some bad predictions
  - The optimal VFS length is very sensitive to the Curve Number
  - MM is a promising tool to test the toolkit to perform UA and GSA at low cost
- Limitations and perspectives:**
- On larger ranges (Curve Number in p.), the current MM is not satisfying (due to a large plateau of null values of the output variable)
  - Continue testing and compare methods on :
    - prediction uncertainty
    - sensitivity of prediction quality to the sampling size
    - global sensitivity analysis (Sobol)

Ref. Carlier, N et al. 2017. *Defining context-specific scenarios to design vegetated buffer zones that limit pesticide transfer via surface runoff*. Sci. Of Total Env., 575. // Munoz-Carpena, R.; Lauvernet, C. & Carlier, N., 2018. *Shallow water table effects on water, sediment, and pesticide transport in vegetative filter strips -- Part 1: nonuniform infiltration and soil water redistribution*. Hydrol. Earth System Sci., 22. // Lauvernet, C. & Munoz-Carpena, R., 2018. *Part 2: model coupling, application, factor importance, and uncertainty*. Hydrol. Earth System Sci., 22. // Chen, Wang & Yang, 2013. *Stochastic Kriging with Qualitative factors*. WSC '13 Proceedings. // Panodou & Roustant, 2017. *mixgp R package: Kriging models for mixed data*.



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## Sampling of the most influent and the most accessible input parameters

Key variable	Sampling range
Curve Number	[ 63 , 99 ]
Slope	[ 2% , 20% ]
Contributive area length(m)	[ 25 , 300 ]
VFS Water table depth (m)	[ 0.5 , 4 ]
Rainfall typical event	Summer/Winter, short/long
VFS Soil type	clo, scl, SIL, CLO, SCL, SAL