



Natural recharge heterogeneity at the catchment scale, in fractured crystalline rock aquifers

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Natural recharge heterogeneity at the catchment scale, in fractured crystalline rock aquifers

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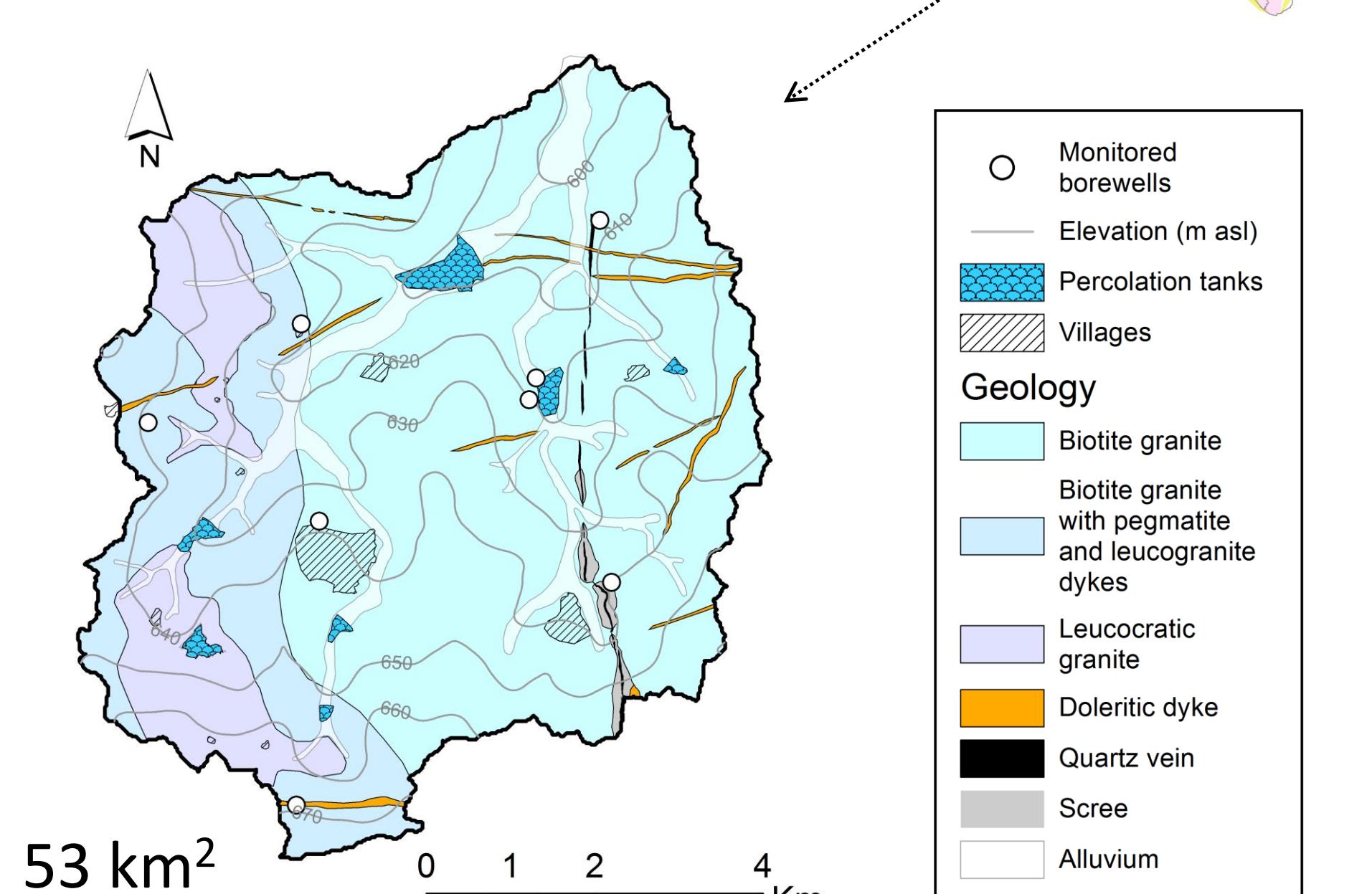
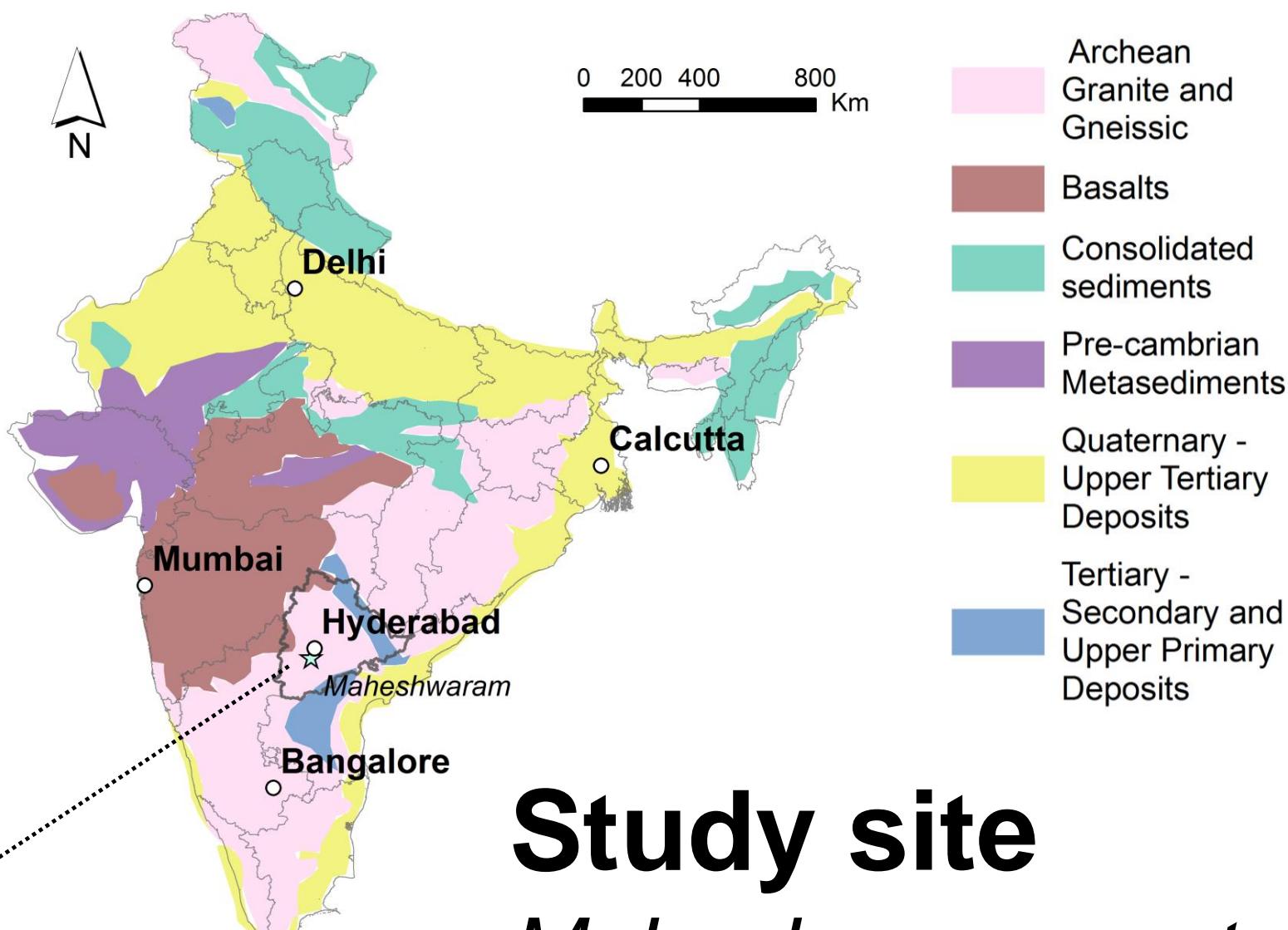
Straightforward estimation of GW recharge at large scales is possible using Water Table Fluctuation methods. However, separating, quantifying and localizing contributions from different recharge processes (diffuse vs. localized) is more difficult, yet crucial in (semi-)arid climates where water stresses and GW overexploitation threaten the livelihoods of those who depend on it.

1. INTRODUCTION AND CONTEXT

Regional scale

Geology & Climate

- Preponderance of igneous rock
 - Low yields
 - Intrinsic heterogeneity and complexity
 - Often only perennial source of freshwater
- Semi-arid climate



Study site

Maheshwaram catchment

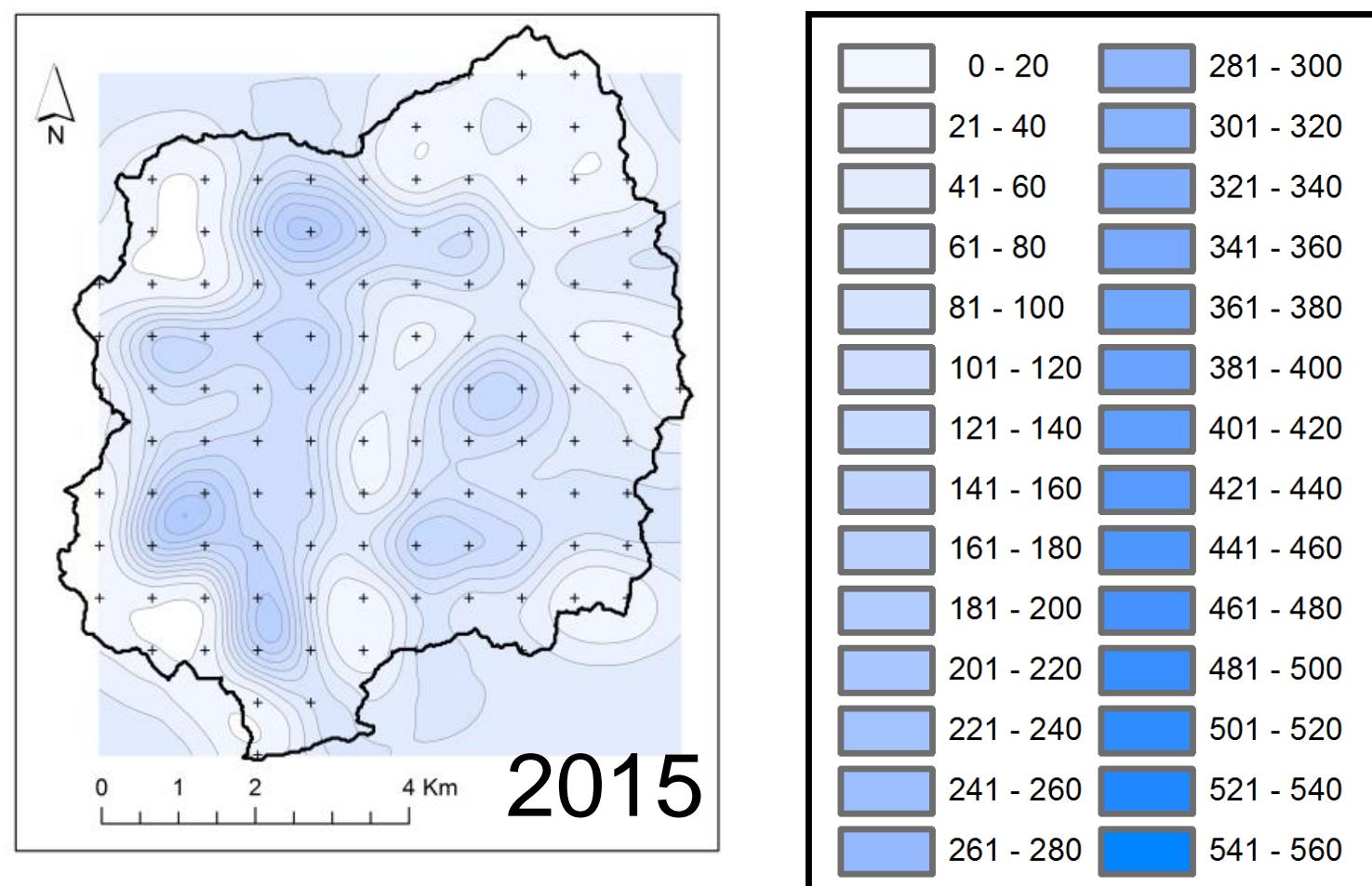
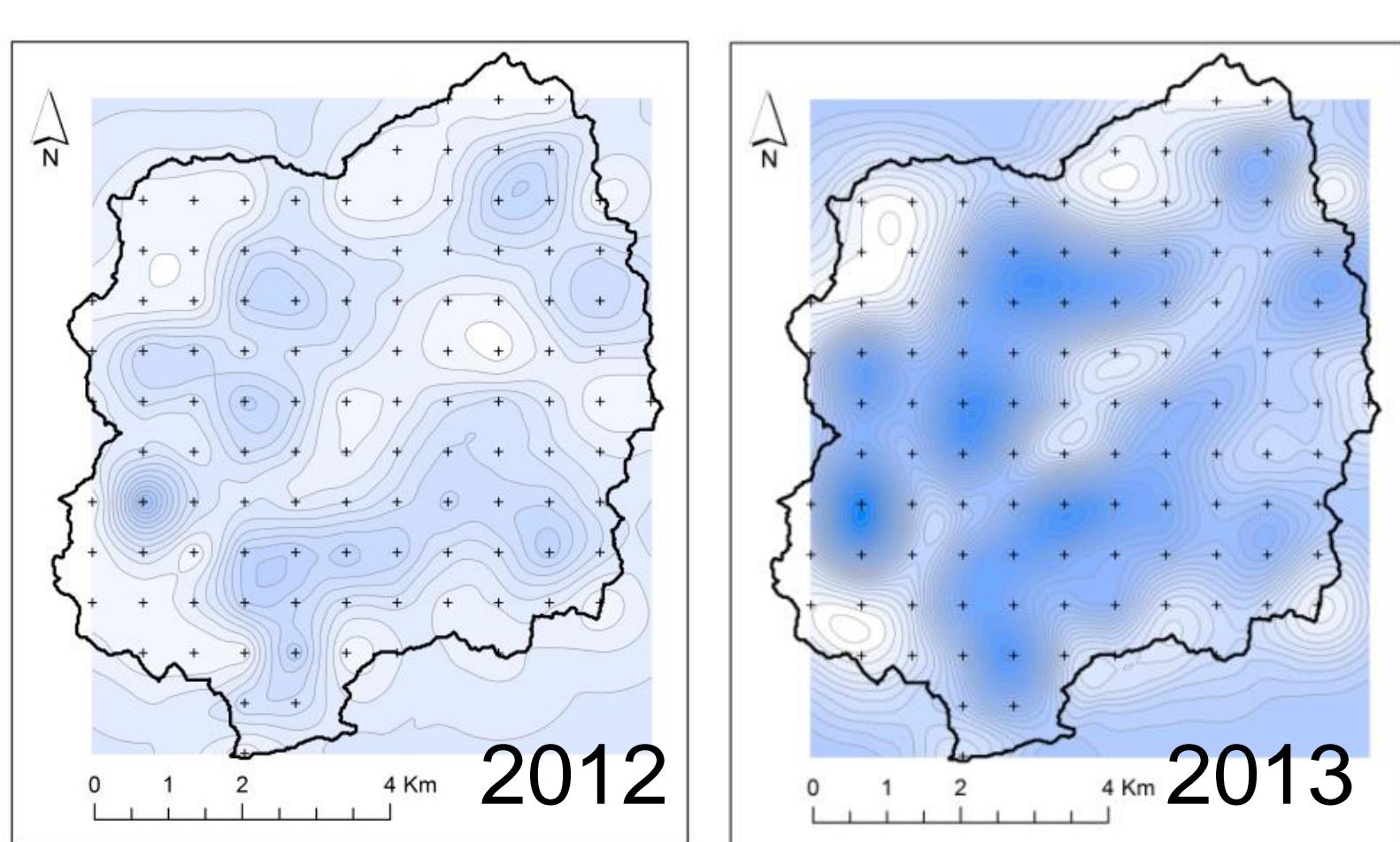
- Rural socio-economy
 - Dominance of rice
 - Highly pumped
- Large amount of data
 - Well known properties (soil type & distribution, hydrodynamic)
 - Long term WL monitoring
 - Seasonal WL campaigns

2. A COMPREHENSIVE MEASURE OF RECHARGE

Reference

Patterns in space

→ Heterogeneous yet recurring recharge patterns



Water Table Fluctuation (WTF) method

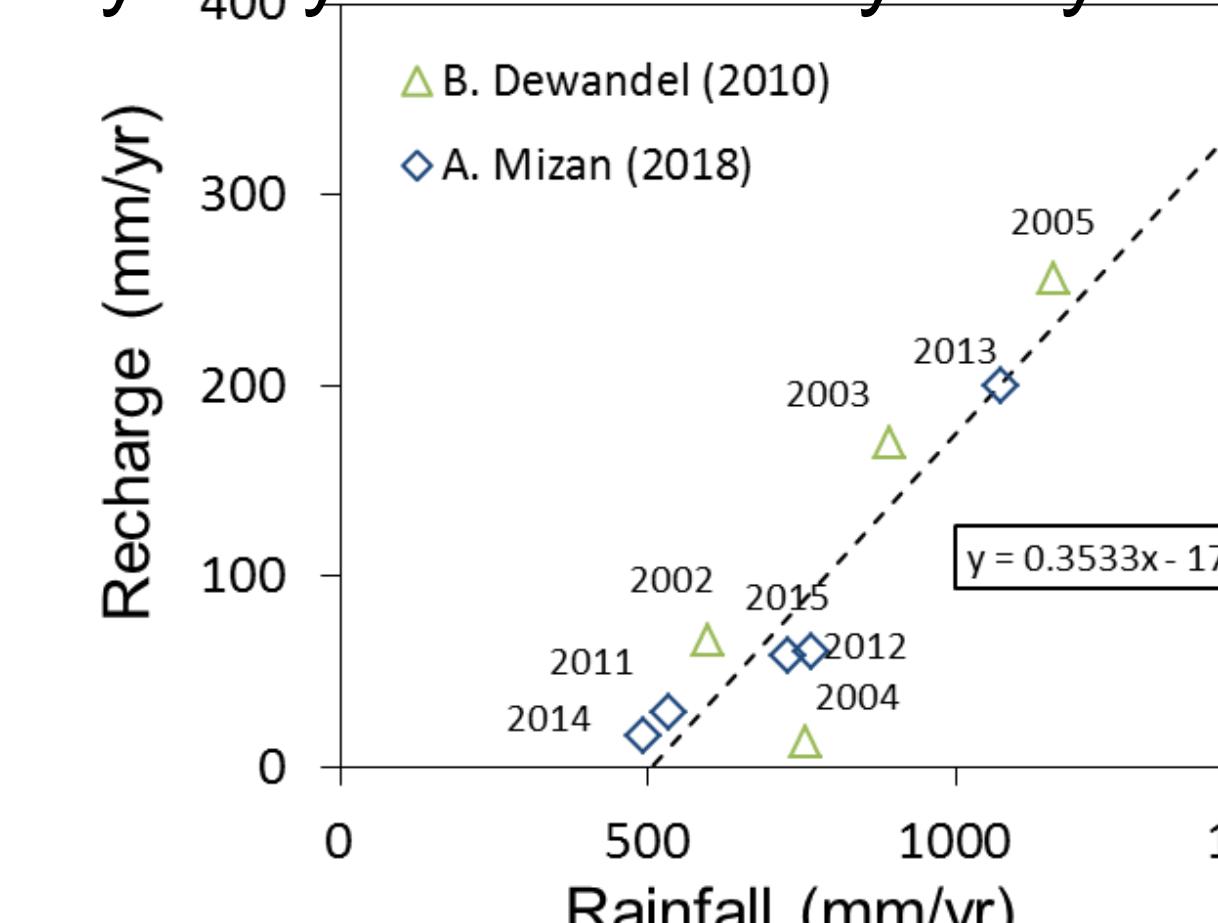
$$R + RF + Q_{in} = E + PG + Q_{off} + S_y \Delta h$$

- Easy and low cost application
- Relatively accurate estimates
- Accuracy depends on accuracy of S_y and Δh
- Integrates both diffuse and focused recharge

see Maréchal et al. (2006)

Recharge relative to total rainfall

→ Linear relationship between yearly rainfall and yearly recharge

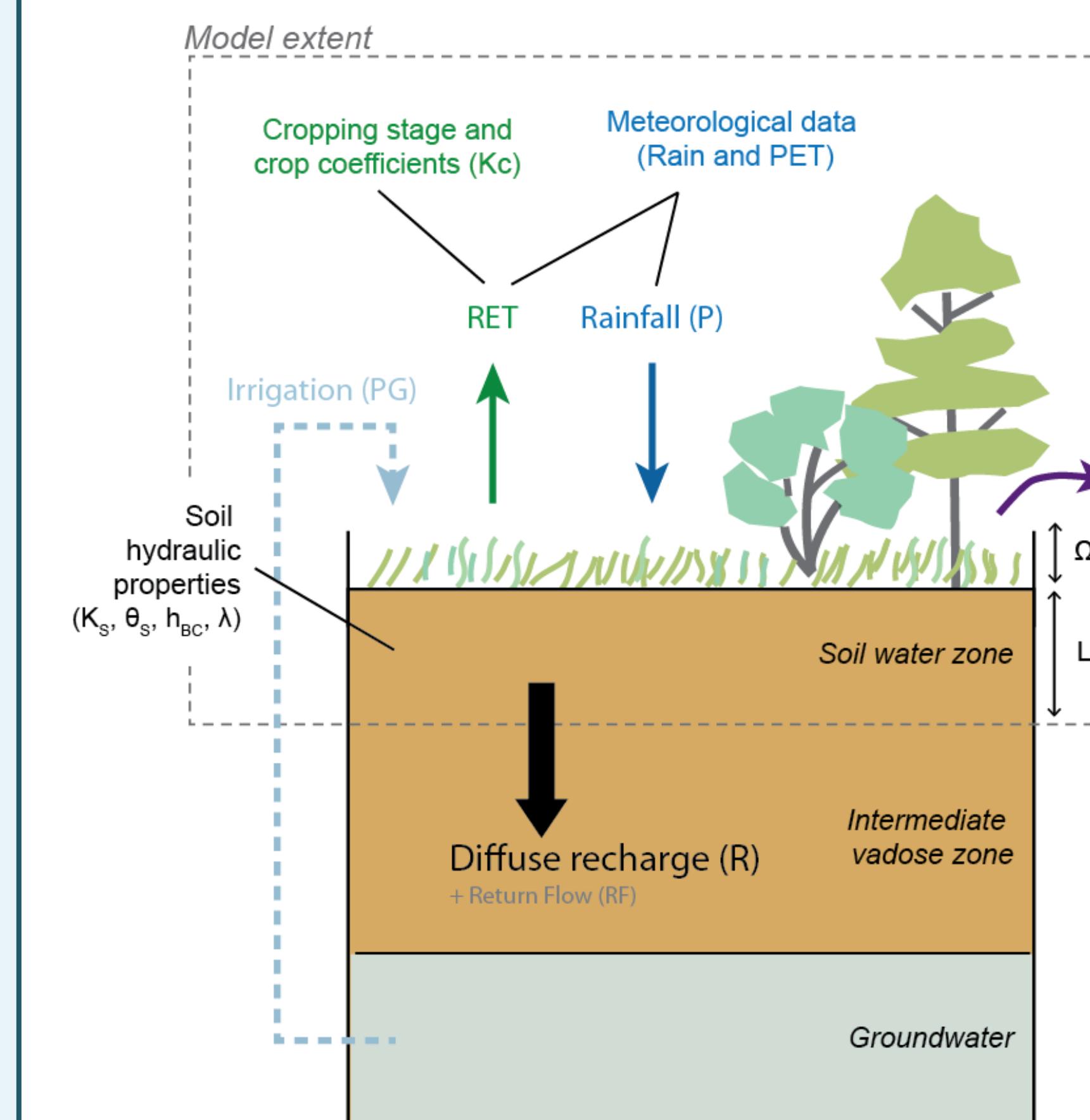


Which recharge mechanisms dominate at large scales in fractured rock?

What is the proportion of localized and indirect recharge to total recharge?

Model overview

Pseudo 2D hydraulic model



Unsaturated eqs.

$$\begin{aligned} h_t(\theta) &= h_{BC} \times \left(\frac{\theta_s}{\theta_t} \right)^{\frac{1}{n}} \\ K_t(\theta) &= K_s \times \left(\frac{\theta_t}{\theta_s} \right)^n \\ q_t &= -K(\theta) \left(\frac{dh}{L} - 1 \right) \end{aligned}$$

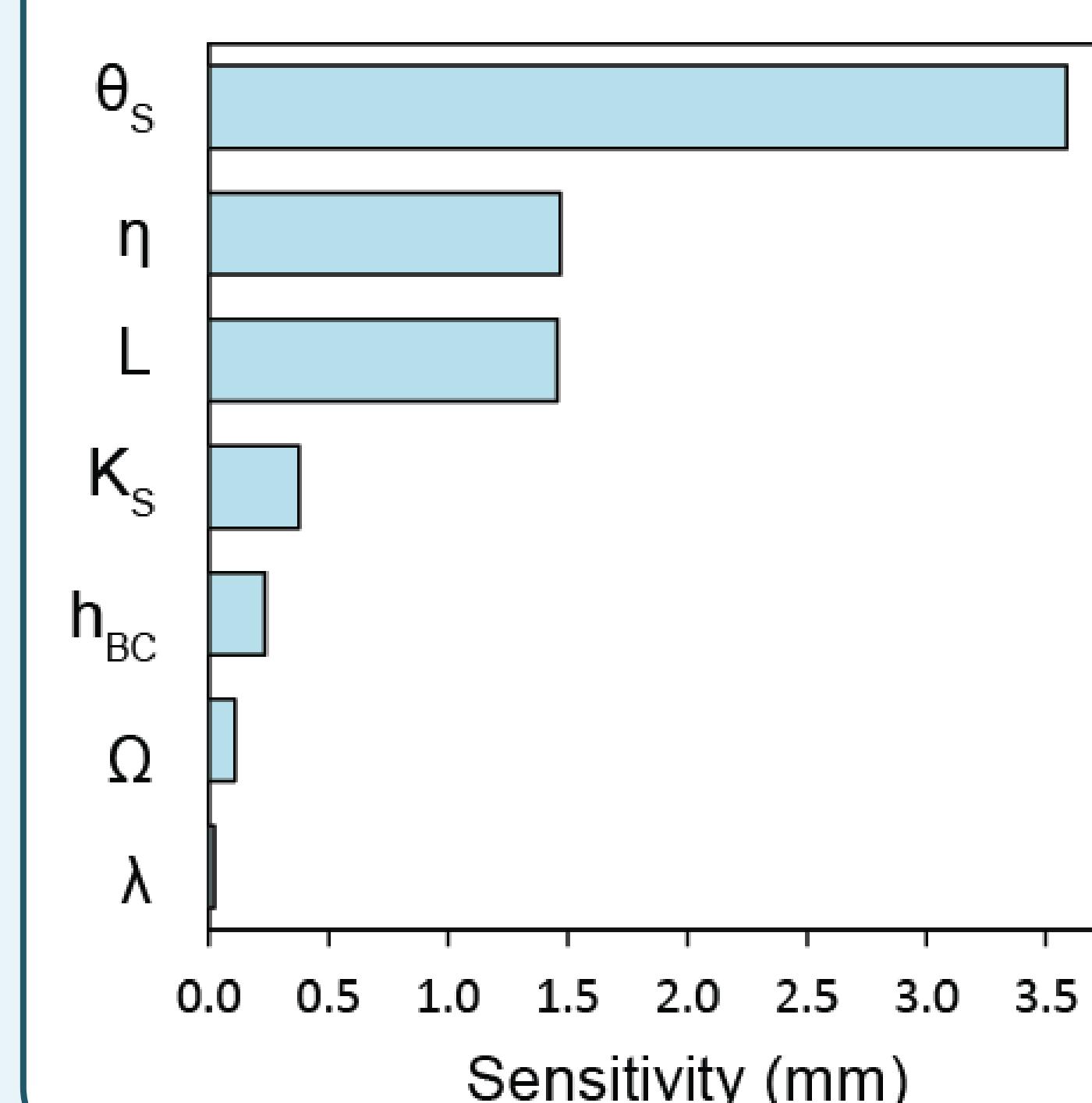
Saturated eqs.

$$\begin{aligned} h &= \text{Inputs}(t) - RET_t - (\theta_s - \theta_{t-1}) \times L \\ K_s & \\ q &= -K_s \left(\frac{dh}{L} - 1 \right) \end{aligned}$$

Sensitivity Analysis

Determine effect of parameter uncertainty on recharge

$$S_{i,t} = P_i \frac{O(P_i + \Delta P_i) - O(P_i)}{\Delta P_i}$$



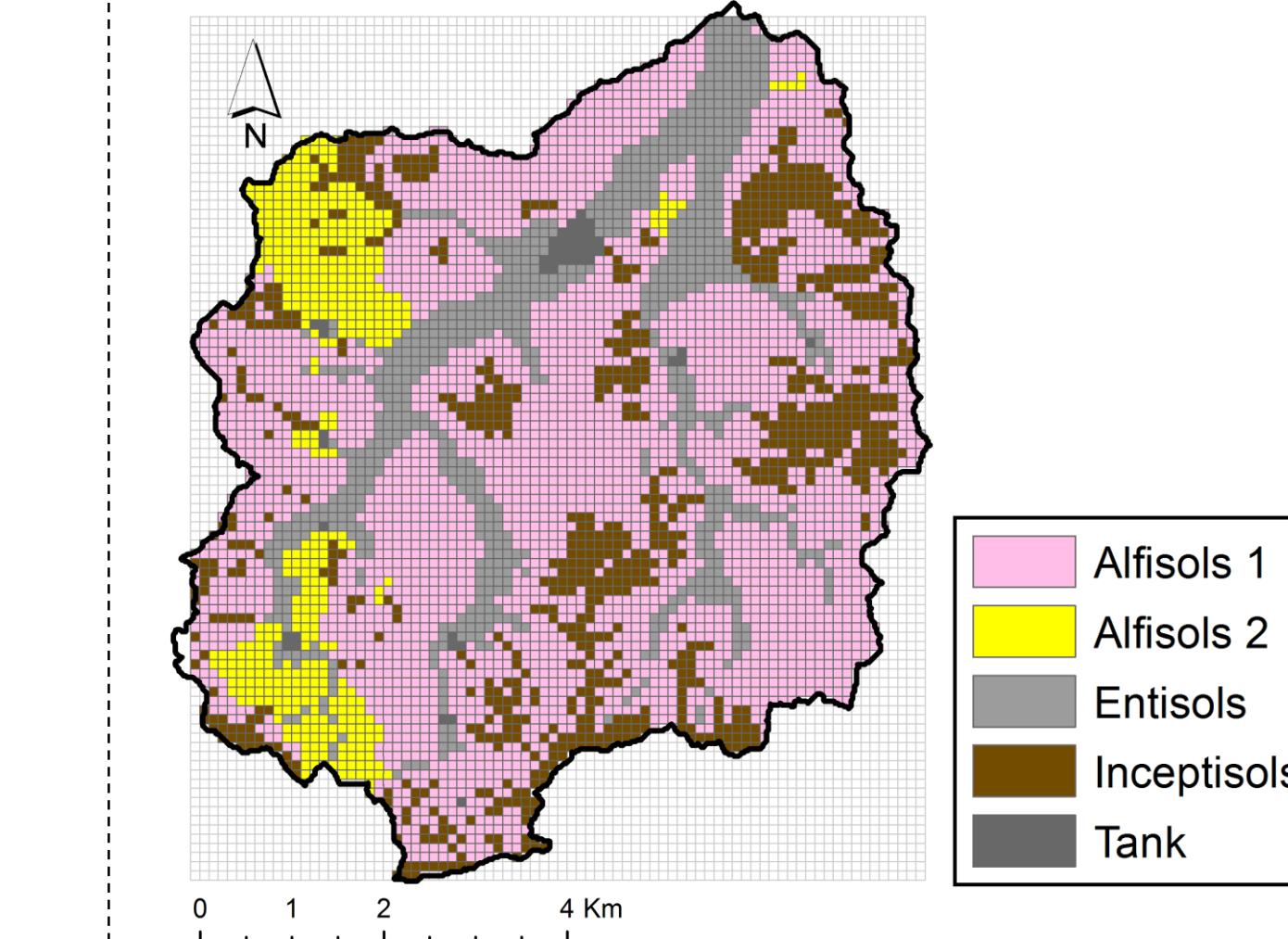
- $S_{i,t}$: Normalized sensitivity of the i^{th} input parameter at time t
- O : Output function of the system
- P_i : i^{th} input parameter

- θ_s : Volumetric moisture content at saturation [m^3/m^3]
- η : Texture dependent retention shape parameter [-]
- L : Soil thickness [m]
- K_s : Hydraulic conductivity at saturation [m/s]
- h_{BC} : Air entry suction [m]
- Ω : Height between top of soil and the top of bordering field edge [m]
- λ : Texture dependent retention shape parameter [-]

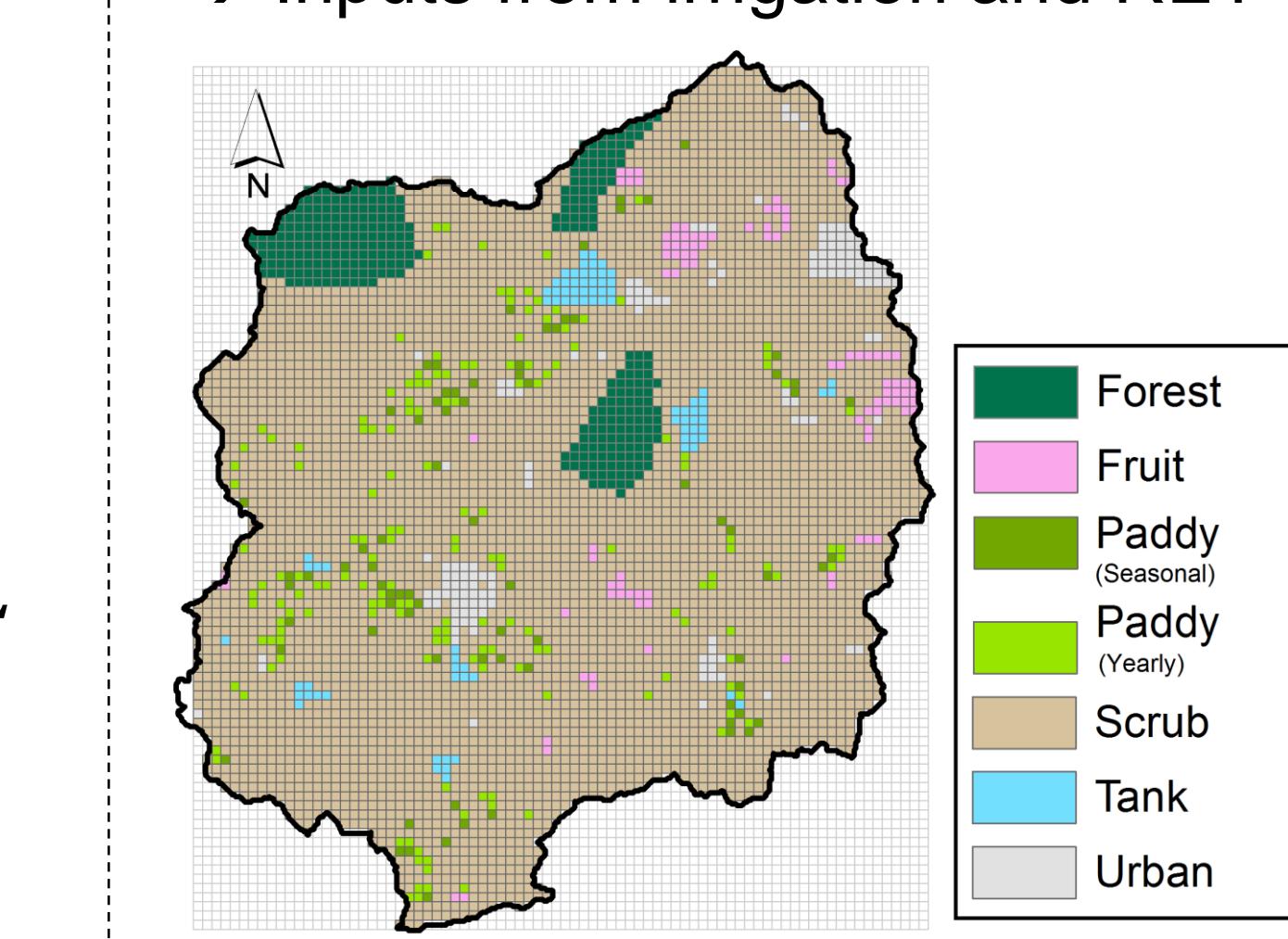
Model inputs

Gridded data from literature & database

Soil Type → Soil hydraulic properties



Land Use & Land Cover → Inputs from irrigation and RET

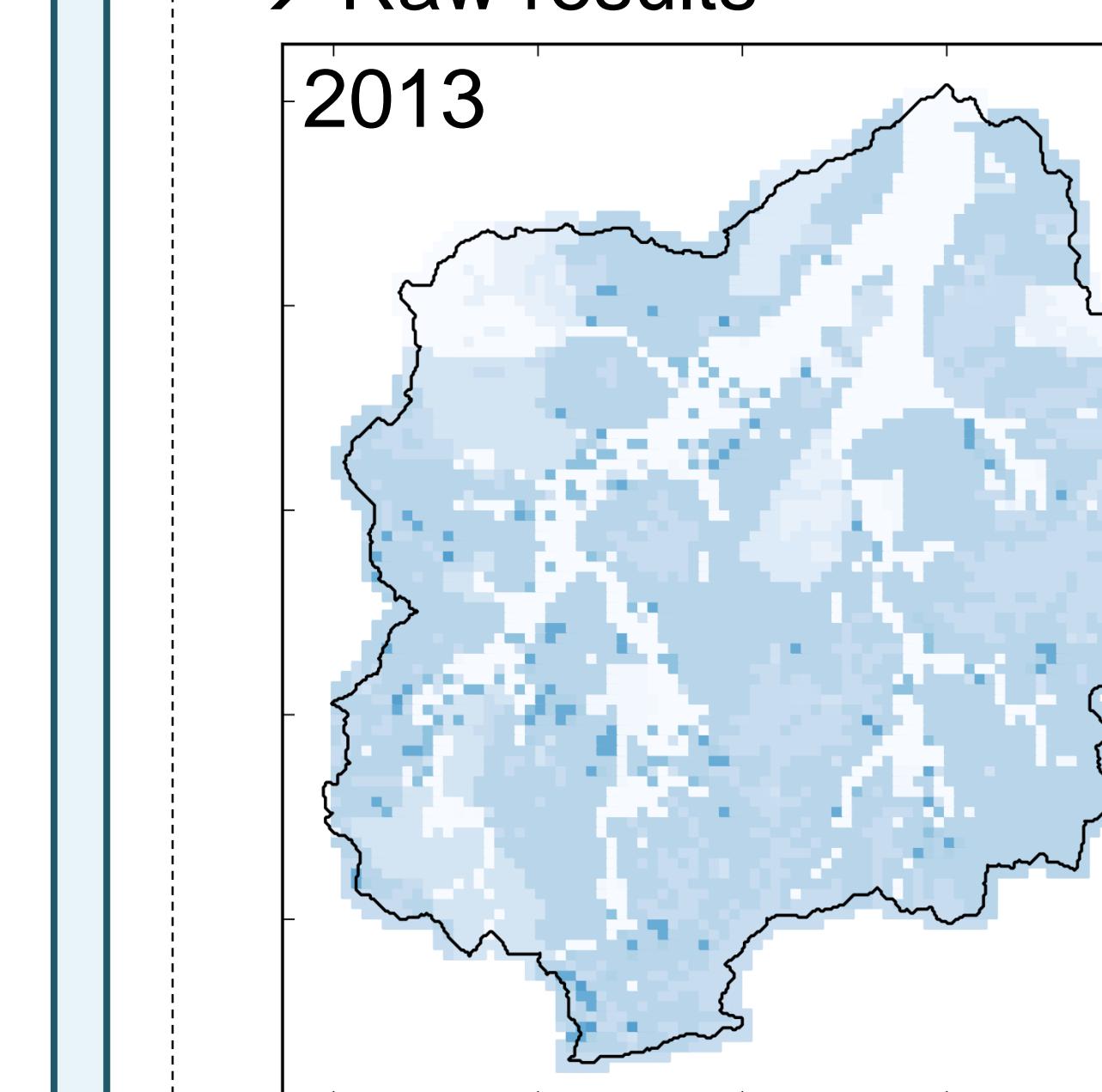


Outputs (mm) Inputs (mm)

3. METHODOLOGY

5. RESULTS

Raw results



- Paddy fields act as zones of enhanced diffuse recharge
- Silty soils in drainage network are antagonistic to diffuse recharge

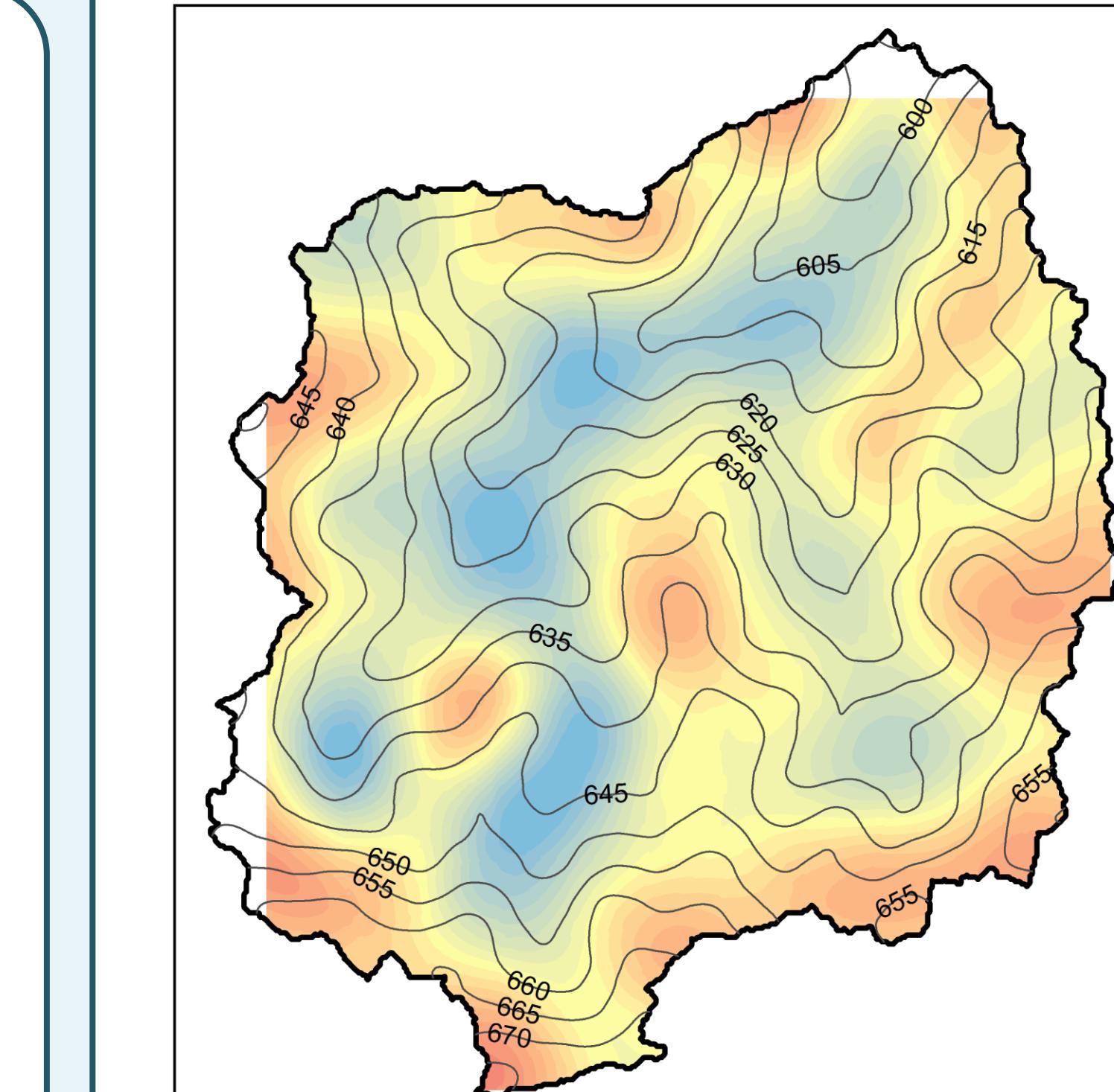
Diff. rech.	Runoff	RET	Rainf.	Irrig.
92	107	725	845	121

- Indirect and localized processes allow for recharge when mean soil moisture is too low

Recharge patterns

Focused recharge (mm/yr)

$$= \text{Total rech.} - \text{Diffuse rech.}$$



de Condappa, D. (2005). Étude de l'écoulement d'eau à travers la Zone Non-Saturée des aquifères de socle à l'échelle spatiale du bassin versant.

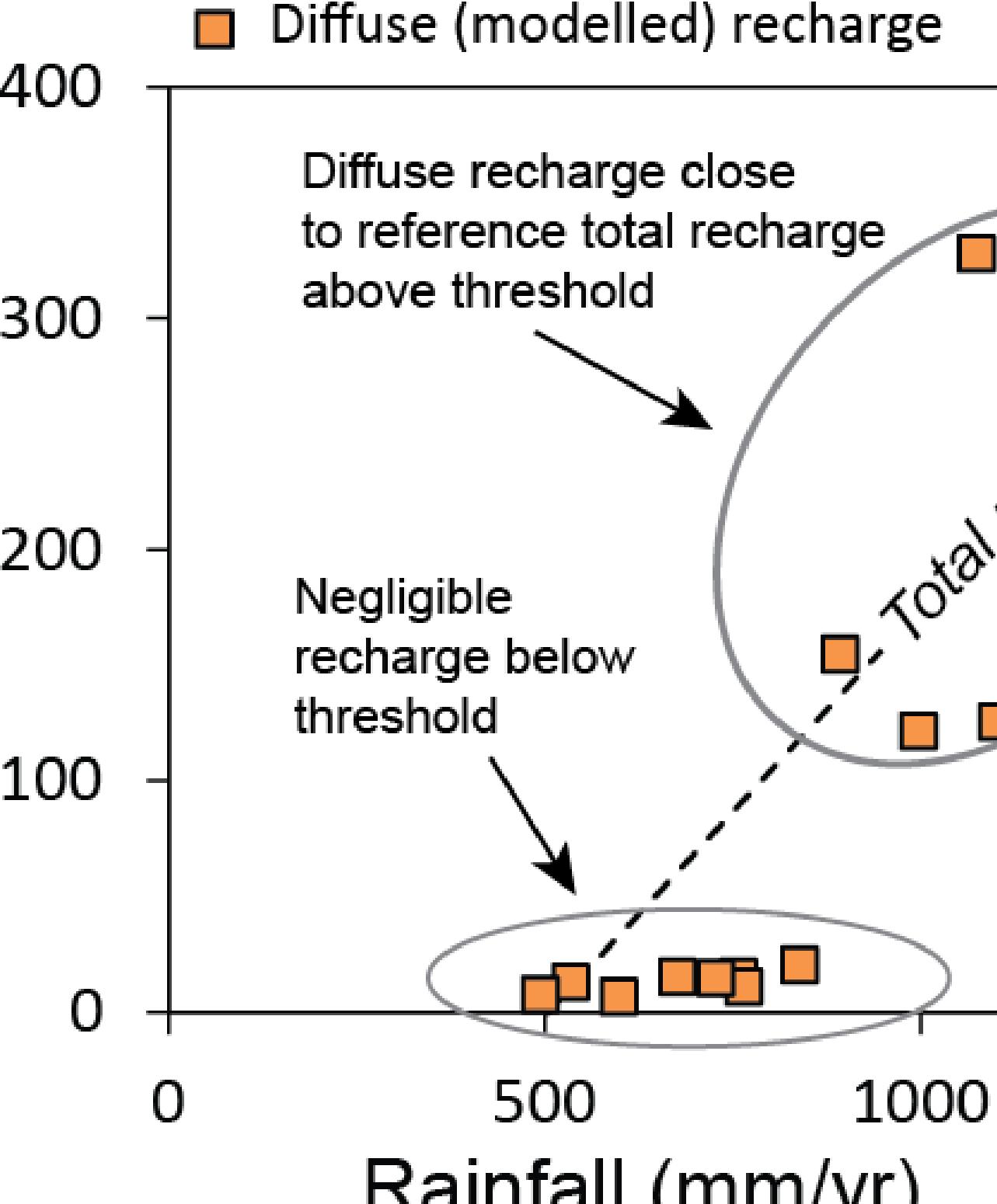
Application à l'estimation de la recharge au sein du bassin versant de Maheshwaram, Andhra Pradesh, Inde. Université Joseph Fourier.

Dewandel, B., Gandolfi, J.-M., de Condappa, D., & Ahmed, S. (2008). An efficient methodology for estimating irrigation return flow coefficients of irrigated crops at watershed and seasonal scale. *Hydrological Processes*, 22(11), 1700–1712.

Maréchal, J. C., Dewandel, B., Ahmed, S., Galeazzi, L., & Zaidi, F. K. (2006). Combined estimation of specific yield and natural recharge in a semi-arid groundwater basin with irrigated agriculture. *Journal of Hydrology*, 281–293.

Mizan, A. (2019). Development of a tool for groundwater management at decisive spatial scale in deeply weathered crystalline aquifers. Submitted to *Hydrological Processes*.

Upscaled results



- Strong correlation to topography
- Despite the non-receptiveness of silty soils, drainage network zones are zones of focused recharge

Indirect recharge in the drainage network plays an important role in recharging the aquifer, especially during dry years when soils are too dry to allow diffuse recharge