

Assessing soil processes importance from global sensitivity analysis performed on soil-plant-atmosphere model DAISY

DELHEZ Laura^{(1)*} & LONGDOZ Bernard⁽¹⁾

INTRODUCTION

Aim of study – In the context of more severe and frequent droughts and waterlogged periods, the objective of this work is to study how edaphic water stress impacts agrosystems functioning using a modelling approach. Before calibrating soil parameters needed to achieve this objective, we must determine which ones have the greatest impact on GHG fluxes. This poster focuses on this procedure through global sensitivity analysis (GSA) performed on data from Lonzée ICOS site.

Model description – DAISY is a mechanistic model simulating the carbon, water and nitrogen processes in the soil-plant-atmosphere continuum. This 1D/2D open-source model quantifies CO₂, H₂O and N₂O fluxes with an hourly time resolution, allowing forthcoming comparison against eddy-covariance data from ICOS sites.

Focus on soil – Soil profile is divided into numerical soil layers (2 to 10 cm) in which organic matter is composed of three pools : added organic matter (AOM), soil microbial biomass (SMB) and soil organic matter (SOM). These pools are split into sub-pools according to their turnover rates (fast, slow & inert). SMB pools release CO₂ and NH₄⁺ in the soil solution during the biodegradation process. Aside from C and N dynamics, soil water flow is described by Richards' equation and van Genuchten function was used to link soil water content and water potential. Above soil profile, evaporation is estimated based on the resistance concept and below soil profile, an aquitard was considered.

METHODOLOGY – Global Sensitivity Analysis (GSA)

The Morris method is considered as a GSA approach that quantifies the influence of parameters in a model among a whole set of parameters p_i . It computes Elementary Effects (EE) of the parameter i on the output Y :

$$EE_i = \frac{Y(p_1, \dots, p_i + \Delta, \dots, p_k) - Y(p_1, \dots, p_i, \dots, p_k)}{\Delta}$$

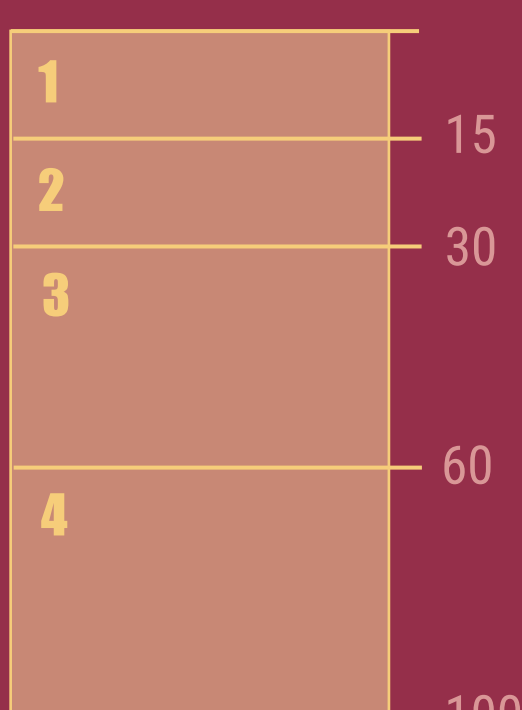
For each parameter, EE_i are computed r times corresponding to r values of Δ . Therefore, each parameter takes r values spread out over its entire range, while local SA only considers the limits of the range.

The computed global sensitivity index is the mean of EE absolute value μ_i^* which estimates the influence of the parameter on the output :

$$\mu_i^* = \frac{1}{r} \sum |EE_i|$$

STUDY SITE

Lonzée Terrestrial Observatory (LTO) is a Class-2 ICOS site. It is located on a 12-ha arable land with a typical Walloon wheat-potato-wheat-sugar beet rotation. Soil texture has been identified as silty loam and soil profile is composed of four soil layers.



GSA was performed over the 2017-2018 season **without vegetation**. Soil water conditions were various during this period. Sensitivity indexes of soil parameters were computed with CO₂ soil production as output.

RESULTS – Analysing time series of sensitivity indexes

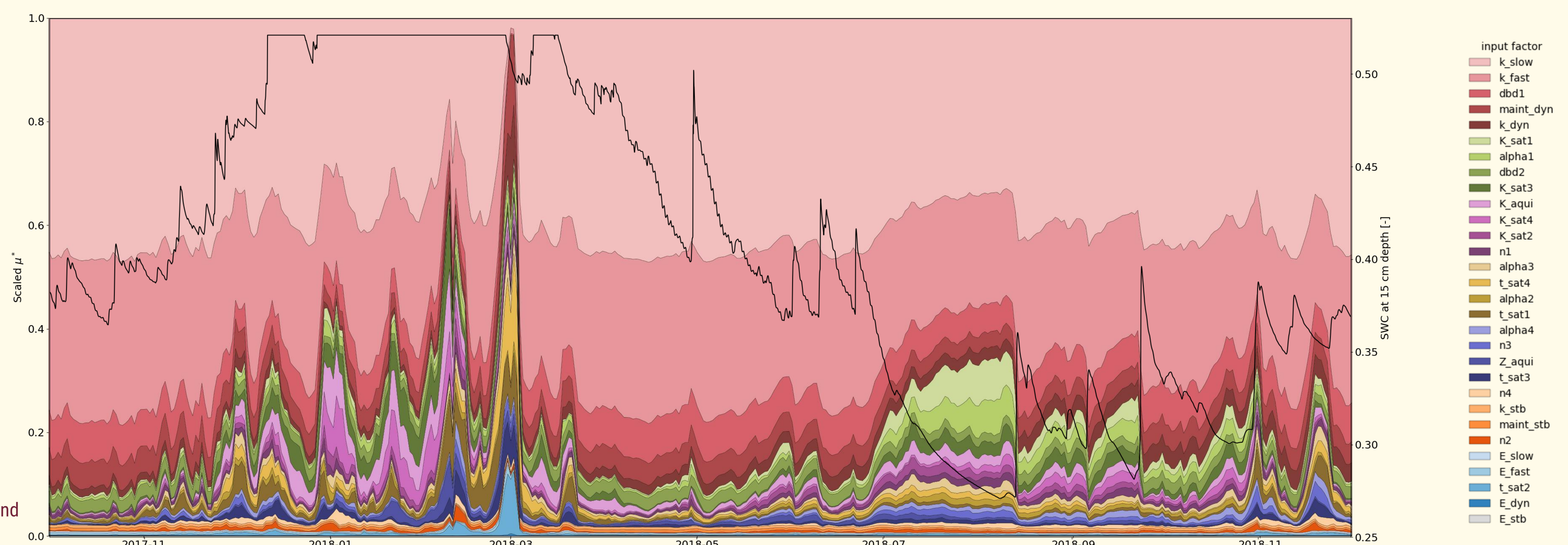


Figure 1 : Scaled μ^* and SWC across time

The figure above represents the temporal evolution of the influence of each parameter μ^* (scaled between [0, 1]) on CO₂ production and of soil water content (black). CO₂ is produced by soil microbial biomass (SMB pools) when decomposing organic matter (SOM pools). As the turnover of SOM pools is based on first-order reaction kinetics, soil respiration is directly proportional to turnover rates of these pools (k_{slow} & k_{fast}), which results in significant values of μ^* . However, even if these two parameters have great impact on CO₂ production, other parameters gain influence during soil saturation or soil drying.

RESULTS – Sensitivity indexes in regard to soil water conditions

The impact of hydraulic parameters on CO₂ production is not globally significant but may become so in particular conditions :

Soil drying – An edaphic drought has been observed during 2018 summer, soil pF at 15 cm depth went above 2.5. Figure 2 shows the ranking of parameters based on their μ^* value averaged over the entire period (first line) and compares it against their μ^* value averaged when $pF > 2.5$ (second line). In these dry conditions, the hydraulic conductivity at saturation (K_{sat}) in light green and the van Genuchten parameter α , both related to the first soil layer, gained a large influence over soil respiration.

Soil saturation – During saturation (from December 2017 to February 2018), K_{sat} of lower soil layers (3rd, 4th layers & aquitard in dark green and light purples on figure 1) have greater influence over soil respiration.

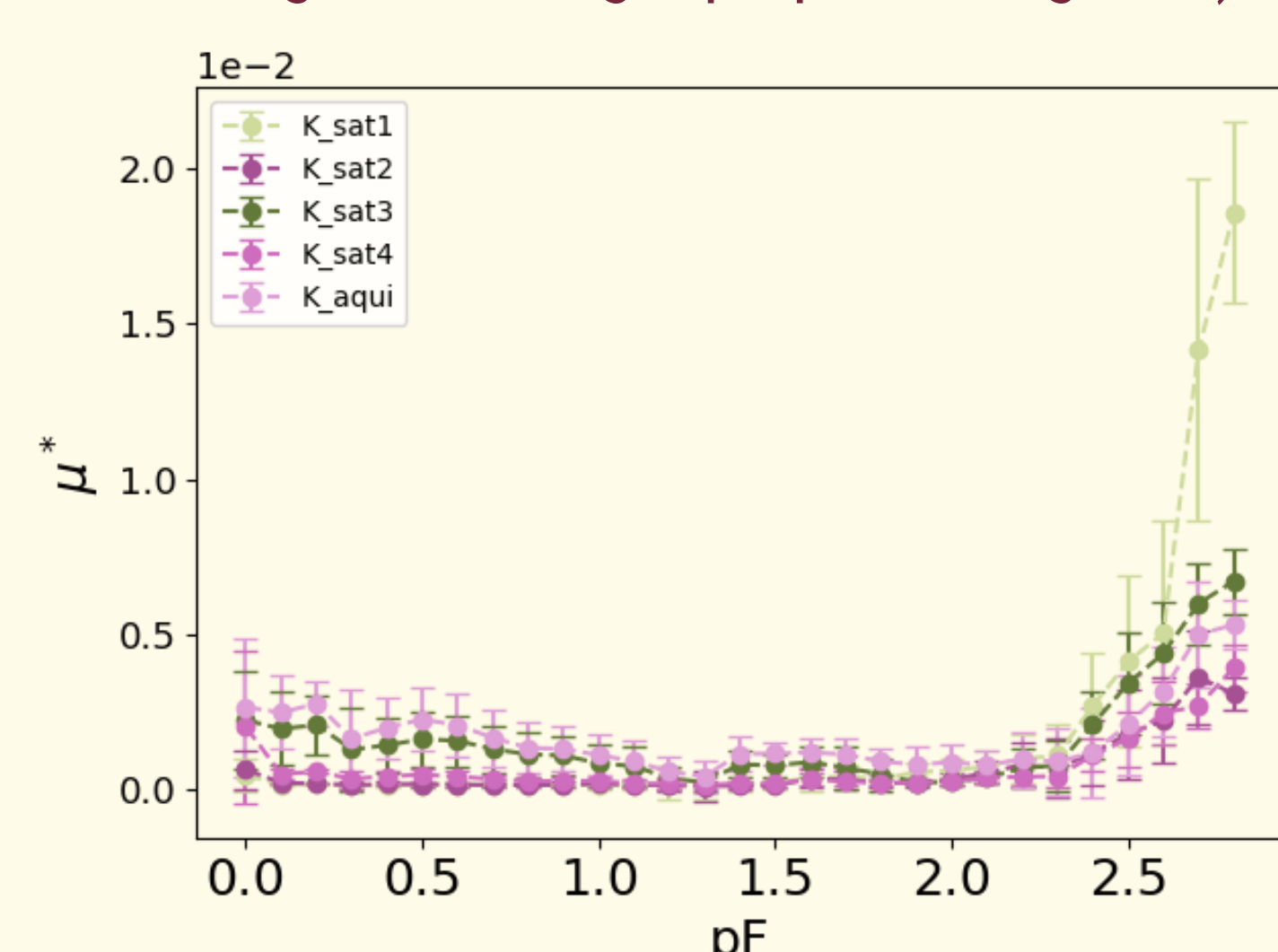


Figure 3 : μ^* values of K_{sat} for different classes of pF

The behaviour of hydraulic parameters can be resumed in figure 3 with K_{sat} as example. The influence of these parameters increases when soil is either drying or saturating/saturated.

The characterisation of these parameters (K_{sat} , α , but also n and θ_{sat}) was the subject of a measuring campaign specific to Lonzée ICOS site.

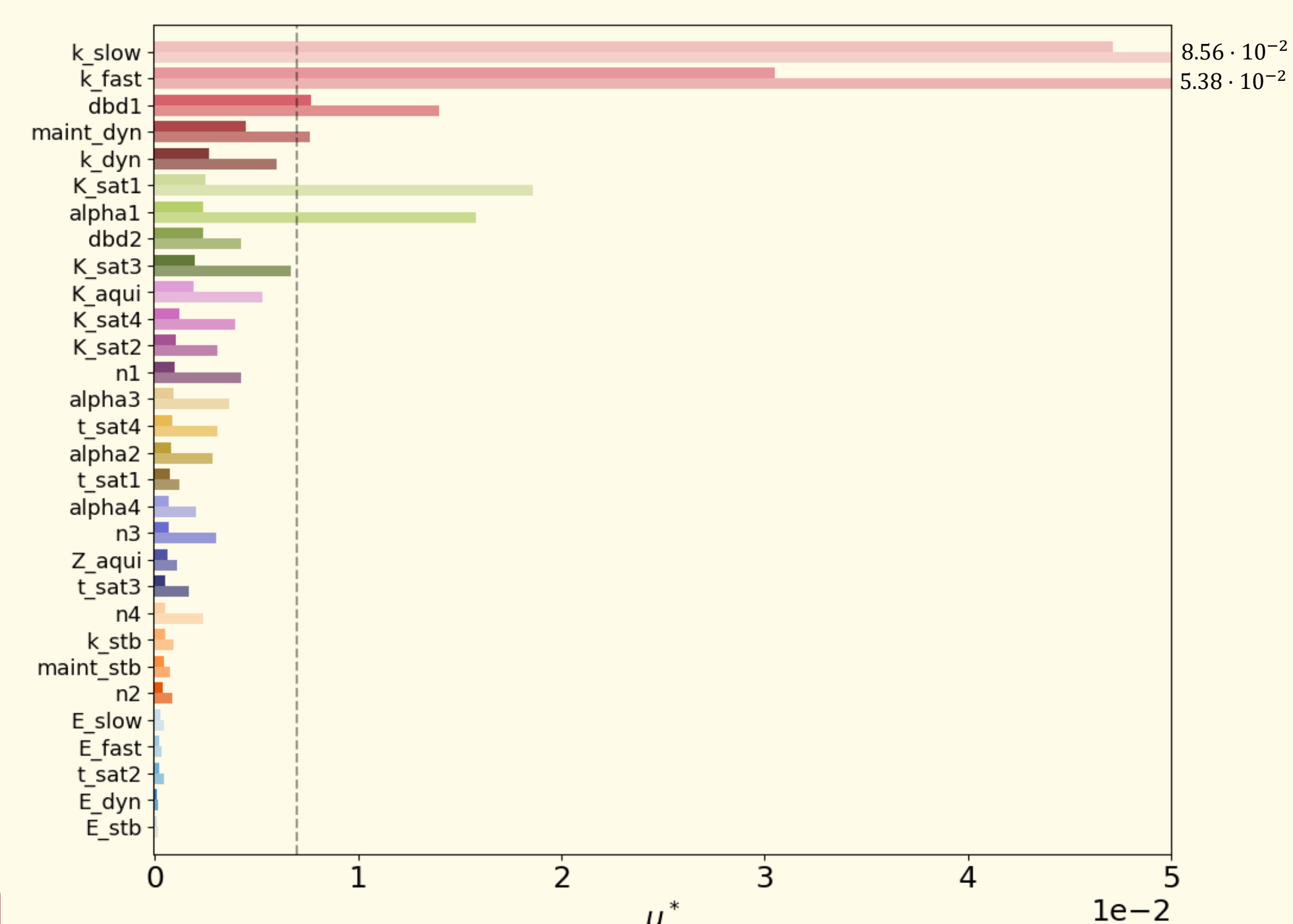


Figure 2 : mean global value of μ^* (above) and mean values of μ^* when $pF > 2.5$ (below)

CONCLUSION

Global sensitivity analysis allows to identify key parameters but is also part of the model understanding. Some parameters have highly variable impact depending on soil water conditions

→ More various conditions means more parameters needing estimation !