Multi-Local and Multi-Global Sensitivity Analysis of Soil Hydraulic Properties: Case of Study of Hydraulically Restrictive Layer.

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Introduction

- Water management on a crop farm requires intelligent irrigation
- Need to maintain optimal moisture conditions in the root zone, which depends on an efficient drainage system
- However, several drainage problems have been identified in crop fields (Gumiere et al., 2014).
- Most of these drainage problems are due to the presence of a restrictive layer in the soil profile.

Objective

- The objective of this work is to evaluate the effects of a restrictive layer on the drainage efficiency by the bias of a multi-local sensitivity analysis.

Material & Methods

Sampling design and solution scheme

- The sensitivity analysis is based on framework of (Cheviron et al., 2010).

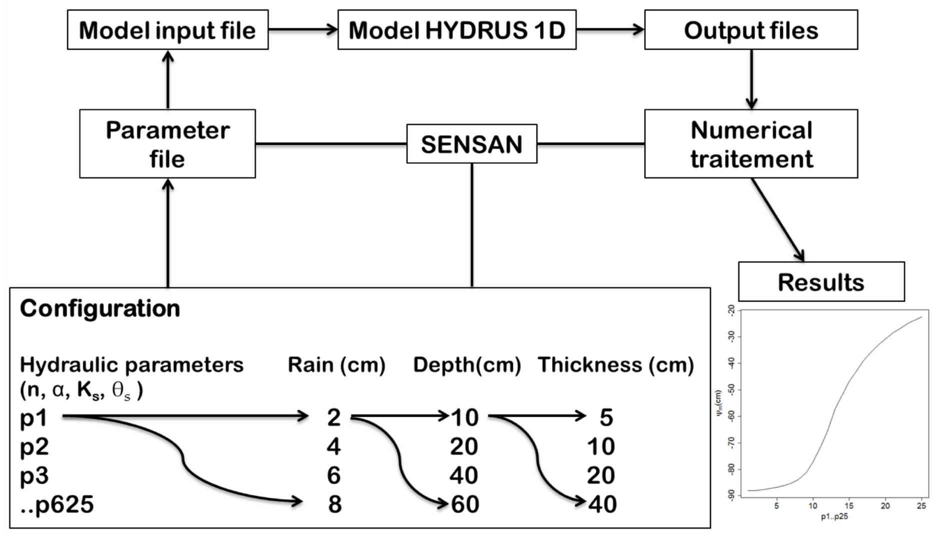

Figure 3. Solution scheme by SENSAN.

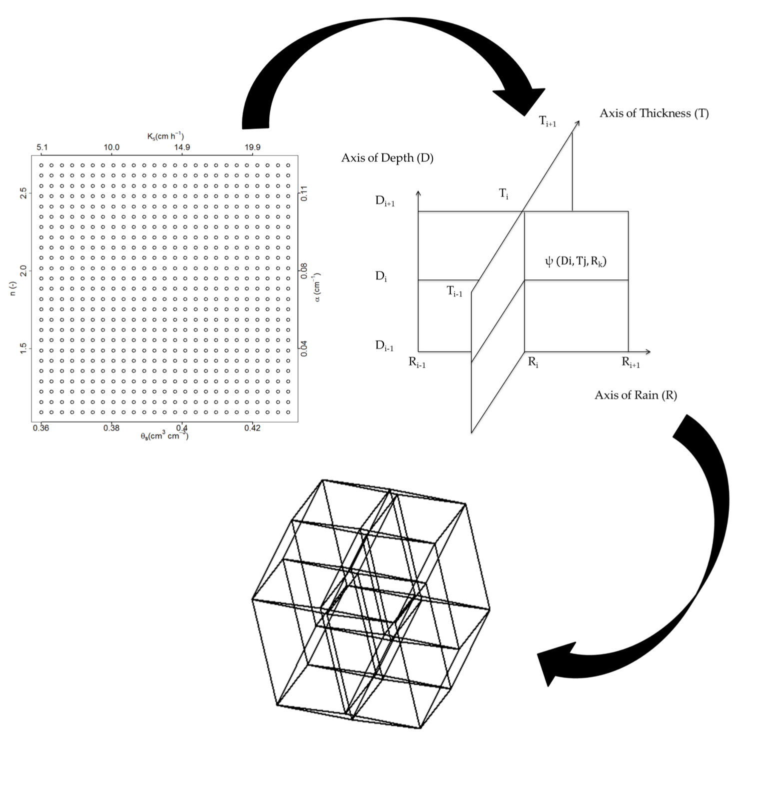

Figure 4. Parameter sampling space in a hypercube with 5 dimensions.

Sensitivity Index Calculation

First order approximation

$$S(p-p_0)=\left.\frac{\partial\psi}{\partial p}\right|_{p_0}=\frac{\psi(p)-\psi(p_0)}{(p-p_0)}$$

Fourth-order approximation

$$S=\left.\frac{\partial\psi}{\partial n}\right|_{n_0}\cdot\left.\frac{\partial\psi}{\partial\alpha}\right|_{\alpha_0}\cdot\left.\frac{\partial\psi}{\partial\theta_s}\right|_{\theta_{s0}}\cdot\left.\frac{\partial\psi}{\partial K_s}\right|_{K_{s0}}$$

Seventh order approximation

$$S_t=\left.\frac{\partial^7\psi}{\partial n\partial\alpha\partial\theta_s\partial K_s\partial R\partial D\partial T}\right|_{n_0,\alpha_0,\theta_{s0},K_{s0},R_0,D_0,T_0}$$

Sensitivity index based on variance decomposition

$$1=\sum_i S_i+\sum_i\sum_{j>i}S_{ij}+\sum_i\sum_{j>i}\sum_{k>j}S_{ijk}+\dots$$

References

Cheviron, B., S.J. Gumiere, Y. Le Bissonnais, R. Moussa and D. Raclot. 2010. Sensitivity analysis of distributed erosion models: Framework. Water Resources Research 46: W08508. doi:10.1029/2009WR007950.

Gumiere, S.J., J.A. Lafond, D. W. Hallema, Y. Périard, J. Caron and J. Gallichand. 2014. Mapping soil hydraulic conductivity and matric potential for water management of cranberry: Characterisation and spatial interpolation methods. Biosystems Engineering, 128: 29-40.

Šimůnek, J., M.T. van Genuchten and M. Šejna. 2008. Development and Applications of the HYDRUS and STANMOD Software Packages and Related Codes. Vadose Zone J. 7: 587-600. doi:10.2136/vzj2007.0077.

Material & Methods

Boundary and initial conditions

- 1D finite element mesh
- Domain was 100 cm in x
- Mesh size = dx = 1 cm
- 101 nodes.
- Observation node at 10 cm of depth

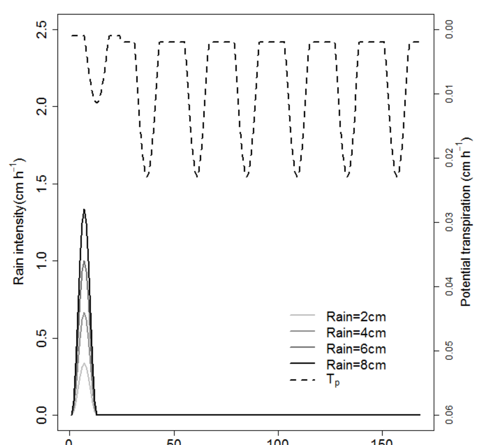

Figure 1. Boundary conditions.

Water flux simulation

Richards' equation

$$C(h)\frac{\partial h}{\partial t}=\frac{\partial}{\partial x}\left[K(h)\left(\frac{\partial h}{\partial x}+1\right)\right]-S(h,x)$$

Mualem (1976) and van Genuchten's (1980) model

$$S_e=\frac{\theta-\theta_r}{\theta_s-\theta_r}=\left[1+(-\alpha h)^n\right]^{-m}$$

$$m=n-\frac{1}{n}$$

$$K(S_e)=K_sS_e^{\,l}\left\{1-\left[1-S_e^{(1/m)}\right]^m\right\}^2$$

$$l=0.5$$

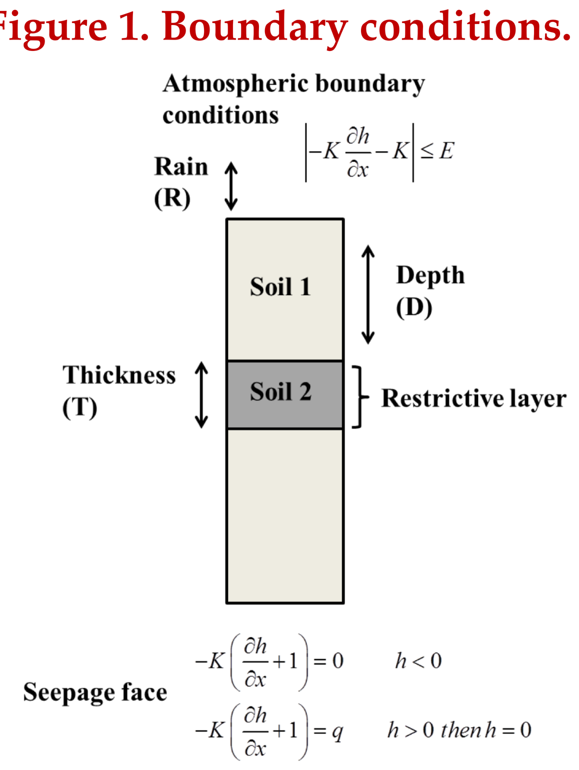

Figure 2. Domain with boundary conditions.

Conclusions

- This study has identified combinations of soil conditions which cause the formation of a perched water table that promotes the maintenance of too long period with matric potential higher than -30 cm.
- Gâteaux directional derivatives have identified the direction and the variation of matric potential according to a change in each conditions.
- The effect of p_{insat} (n and α) is very important compared to p_{sat} (K_s and θ_s) .
- According to the Gâteaux directional derivatives, it is clear that the hydraulic properties of the restrictive layer are the most sensitive conditions.
- The depth of the layer is more sensitive than the thickness.
- The precipitation conditions were very insensitive.

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Results

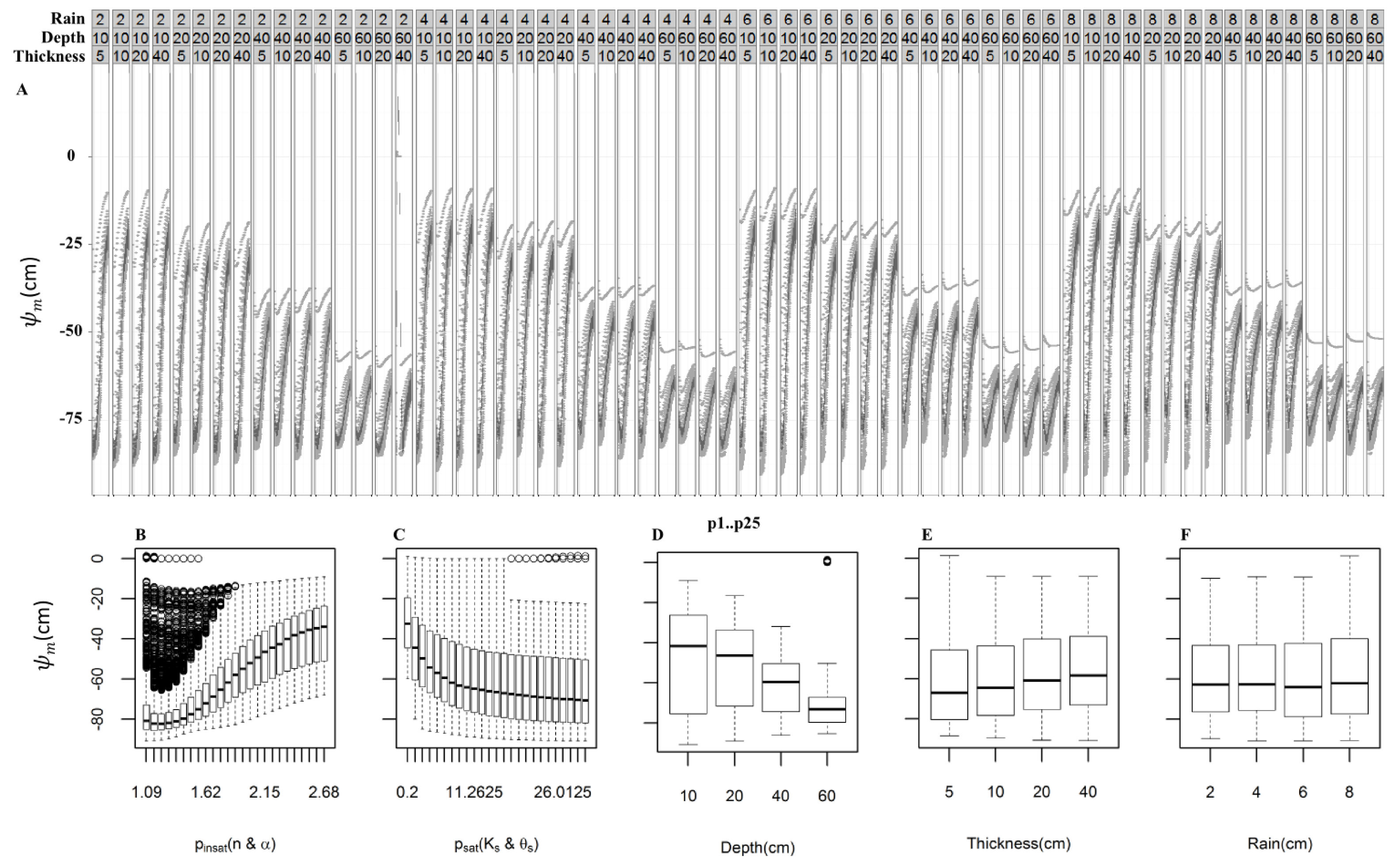


Figure 5. (A) Matric potential at 24 hours after the highest level of the water table after precipitation according to different conditions (hydrodynamic, physical and climatic) and their represention in a boxplot according to each level of: (B) pinsat, (C) psat, (D) physical condition of depth, (E) physical condition of thickness and (F) climatic condition of rain.

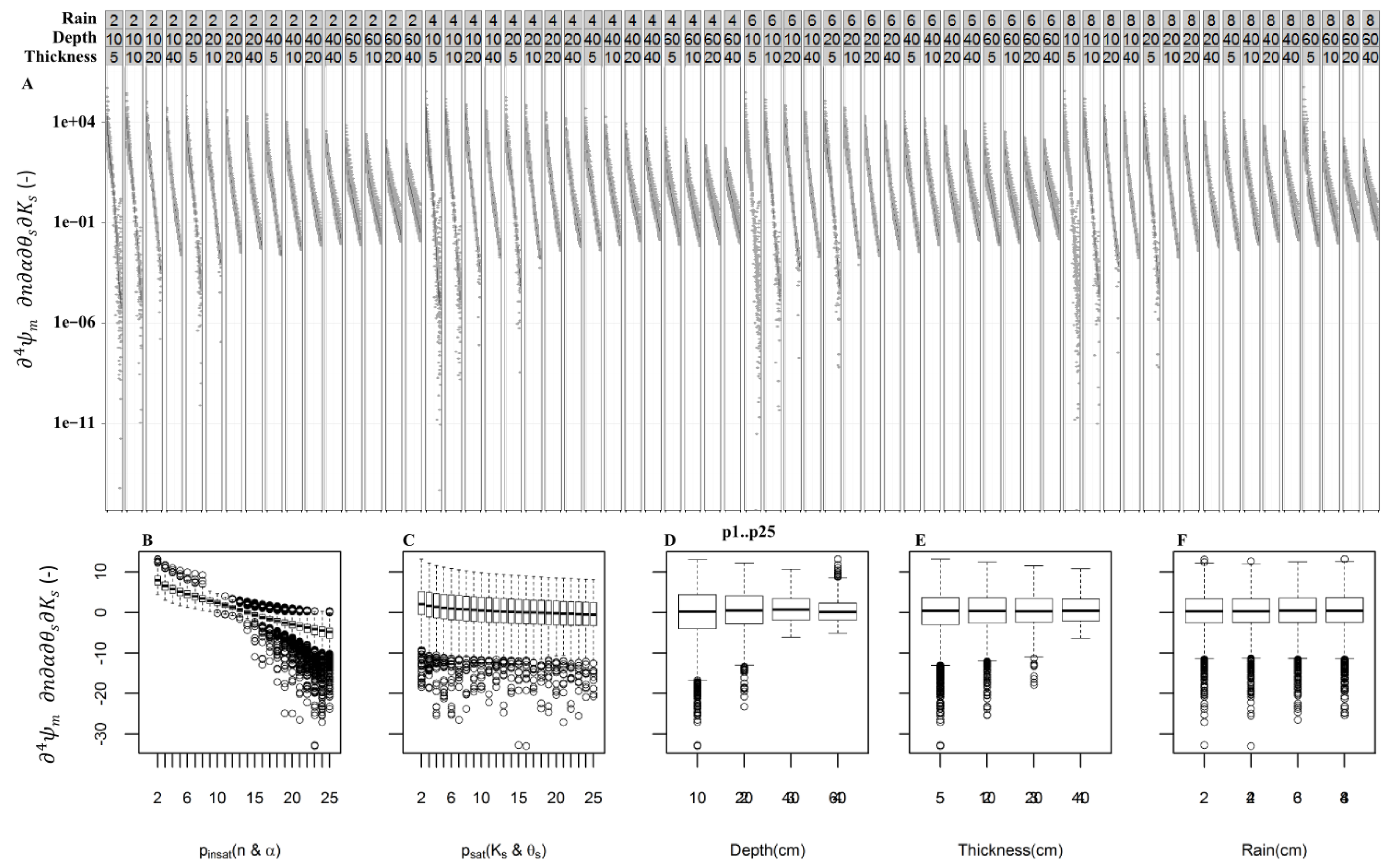


Figure 6. (A) Fourth order Gâteaux directional derivative of the soil hydraulic parameters according to different conditions (hydrodynamic, physical and climatic) and their represention in a boxplot according to each level of: (B) p_{insat}, (C) p_{sat}, (D) physical condition of depth, (E) physical condition of thickness and (F) climatic condition of rain.

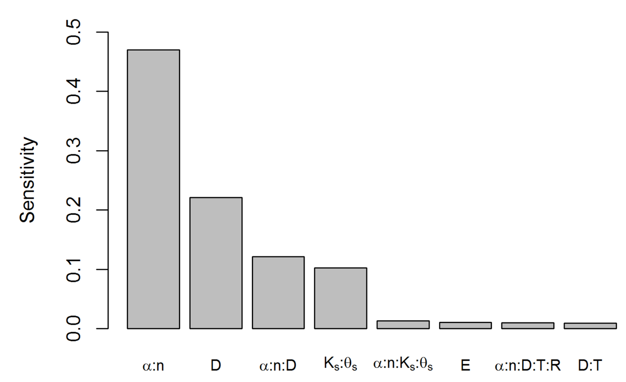
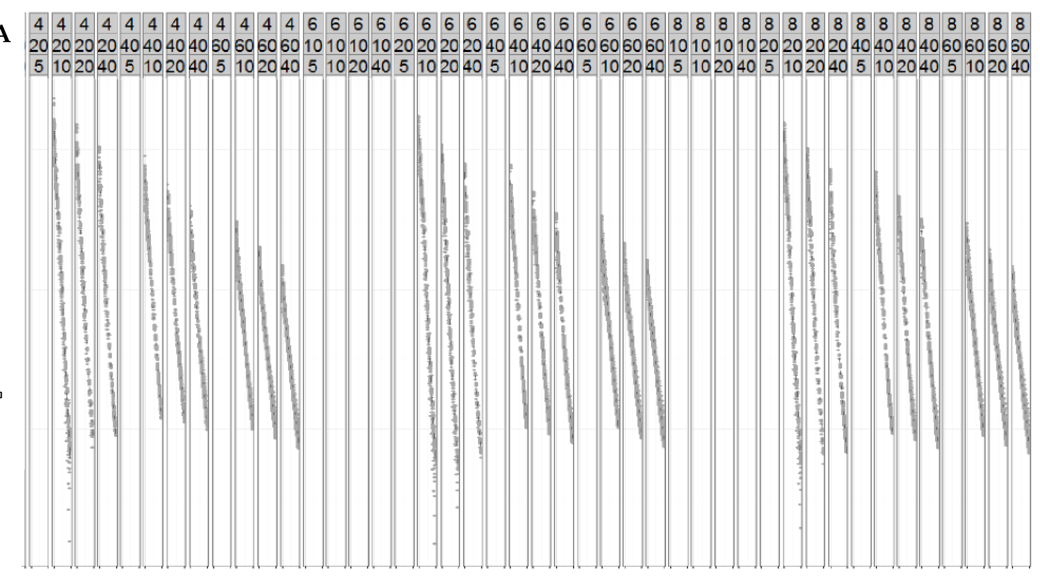


Figure 7. Global sensitivity based on variance decomposition



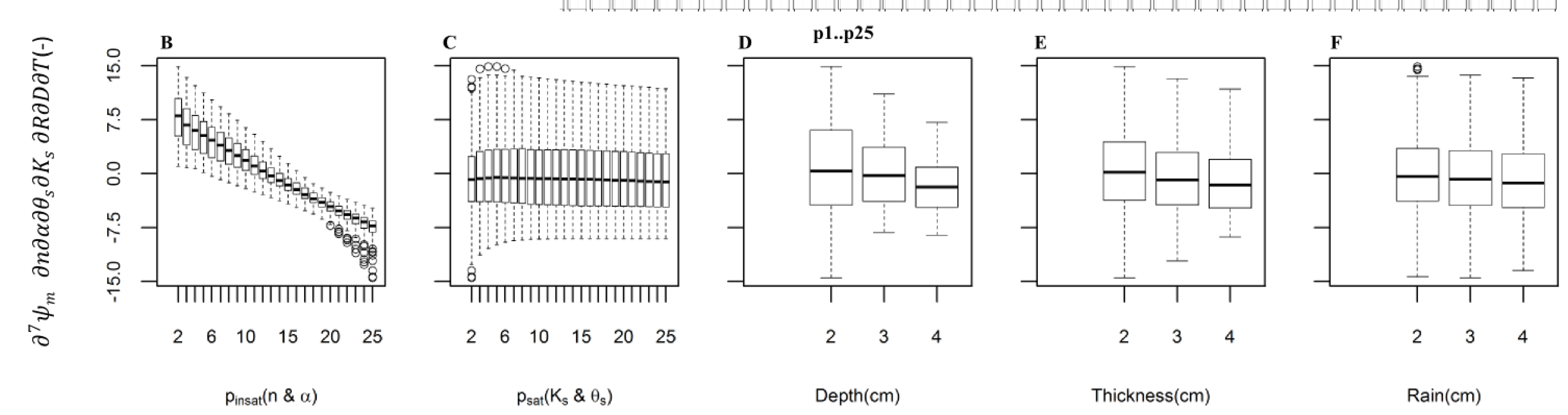


Figure 8. (A) Seven order Gâteaux directional derivative according to different conditions (hydrodynamic, physical and climatic) and their represention in a boxplot according to each level of: (B) pinsat, (C) psat, (D) physical condition of depth, (E) physical condition of thickness and (F) climatic condition of rain.