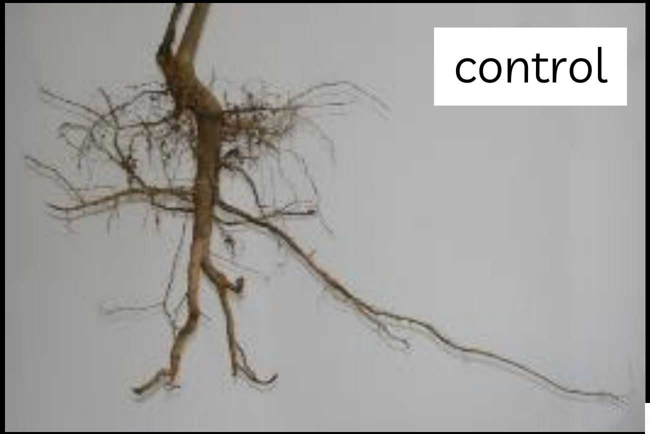
VSoilForOAD project

Development of a prototype of climate service

“forest_soil_practicability_prevision_tool”

Limit the forest surface affected by soil compaction and rutting



Heavy traffic on forest soils => strong and long lasting impacts on soils and trees :

-increased soil density and resistance to penetration, water logging intensity or erosion…

-decreased soil water conductivity and gas diffusivity, biological activity, roots development (on average -30% on root depth, Mariotti et al. 2020), trees growth (on average -20% on biomass, Mariotti et al. 2020)…

trafficked	control

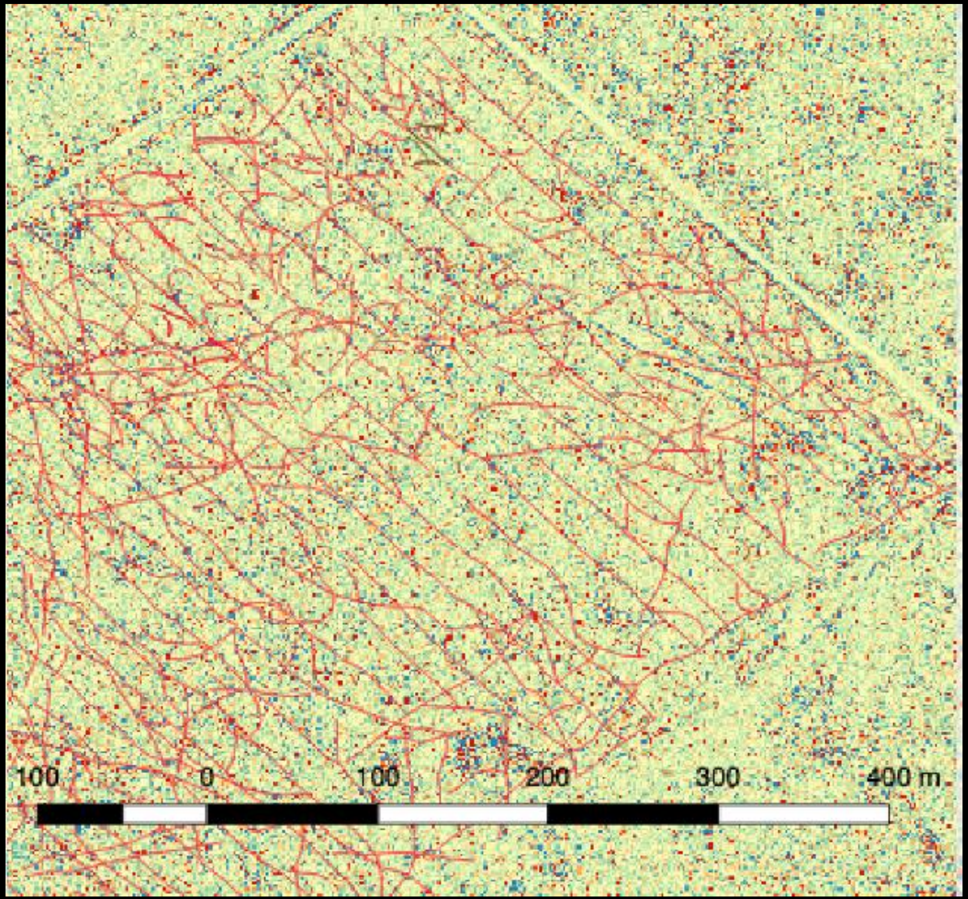
Solutions :

-cable yarding systems, horse…

-**concentration of machinery traffic on permanent skidding trails**

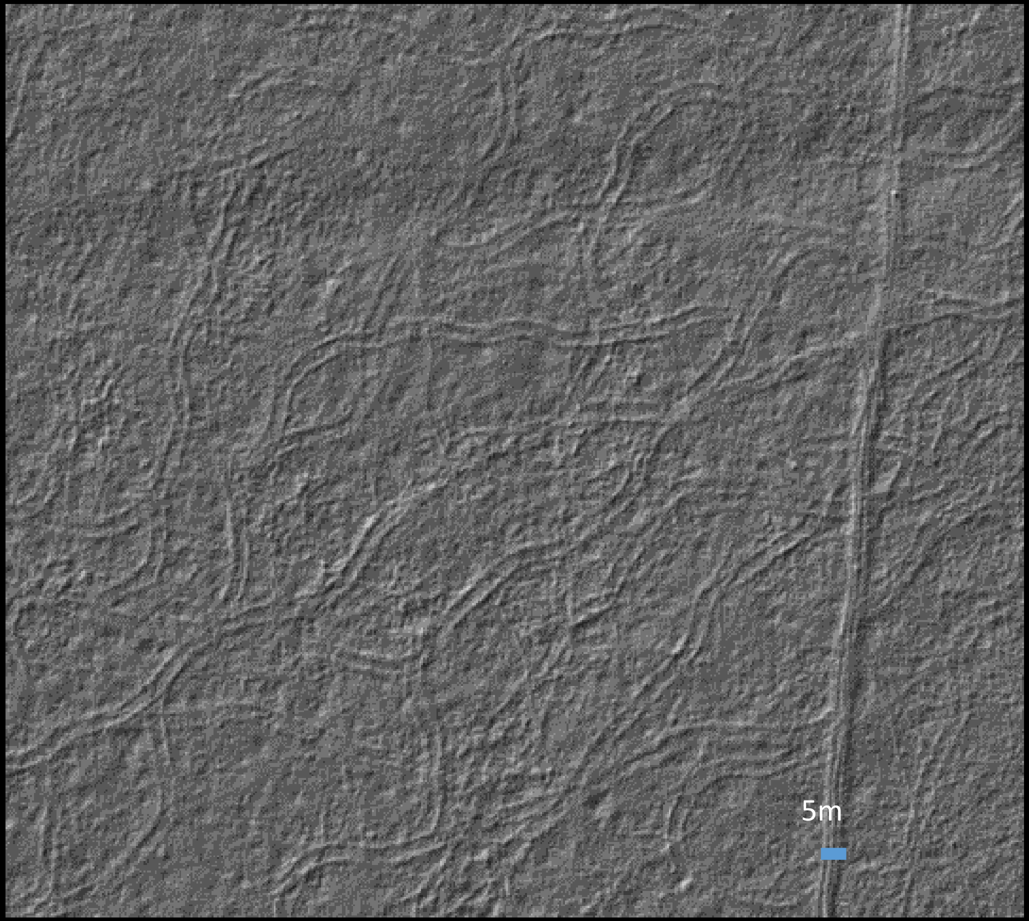
Limit the forest surface affected by soil compaction and rutting

% of trafficked surface with the implementation of skid trails : in theory 20% (4m every 20m)



FD Compiègne, treatment of LIDAR data : Mohieddinne, 2019

% of trafficked surface without skid trails : mean per harvesting operation = 34%, max = 60% + CUMULATIVE increase



FD Chantilly, treatment of LIDAR data : Bock, 2022

Limit the forest surface affected by soil compaction and rutting

ADEME Les clés pour Agir 2021

Adapt the planning of harvesting operations to soil water status:

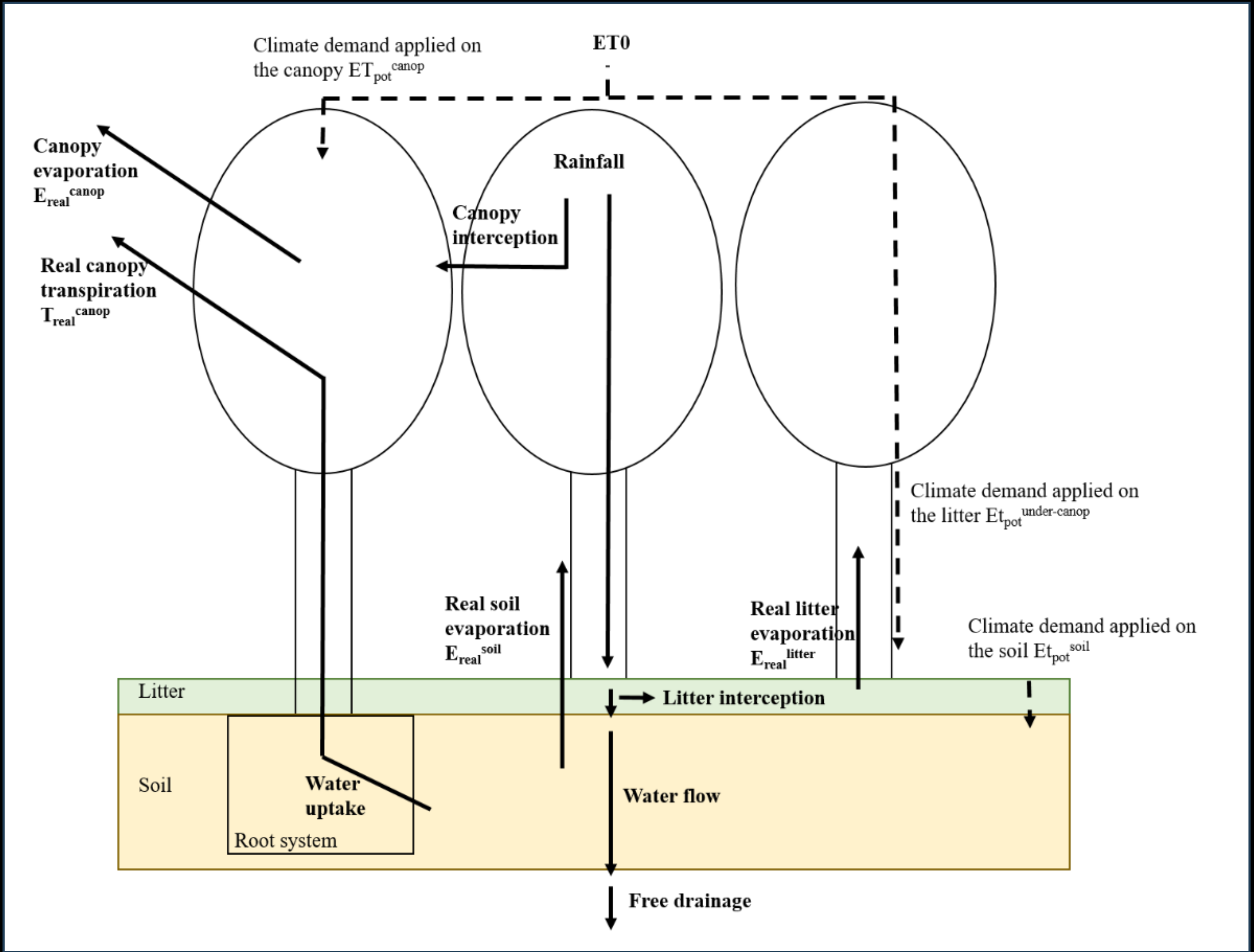
Soil water status	Heavy traffic on skid trails
dry	
wet	>50% stones Sandy and clayey Silty
Water table between 0 and 50cm depth	

Limit the forest surface affected by soil compaction and rutting

Aim of the VSoilForOAD project :
develop a prototype of a climate service predicting, in real time and for the next 14 days, the load-bearing capacity of skid trails.

Description of the climate service

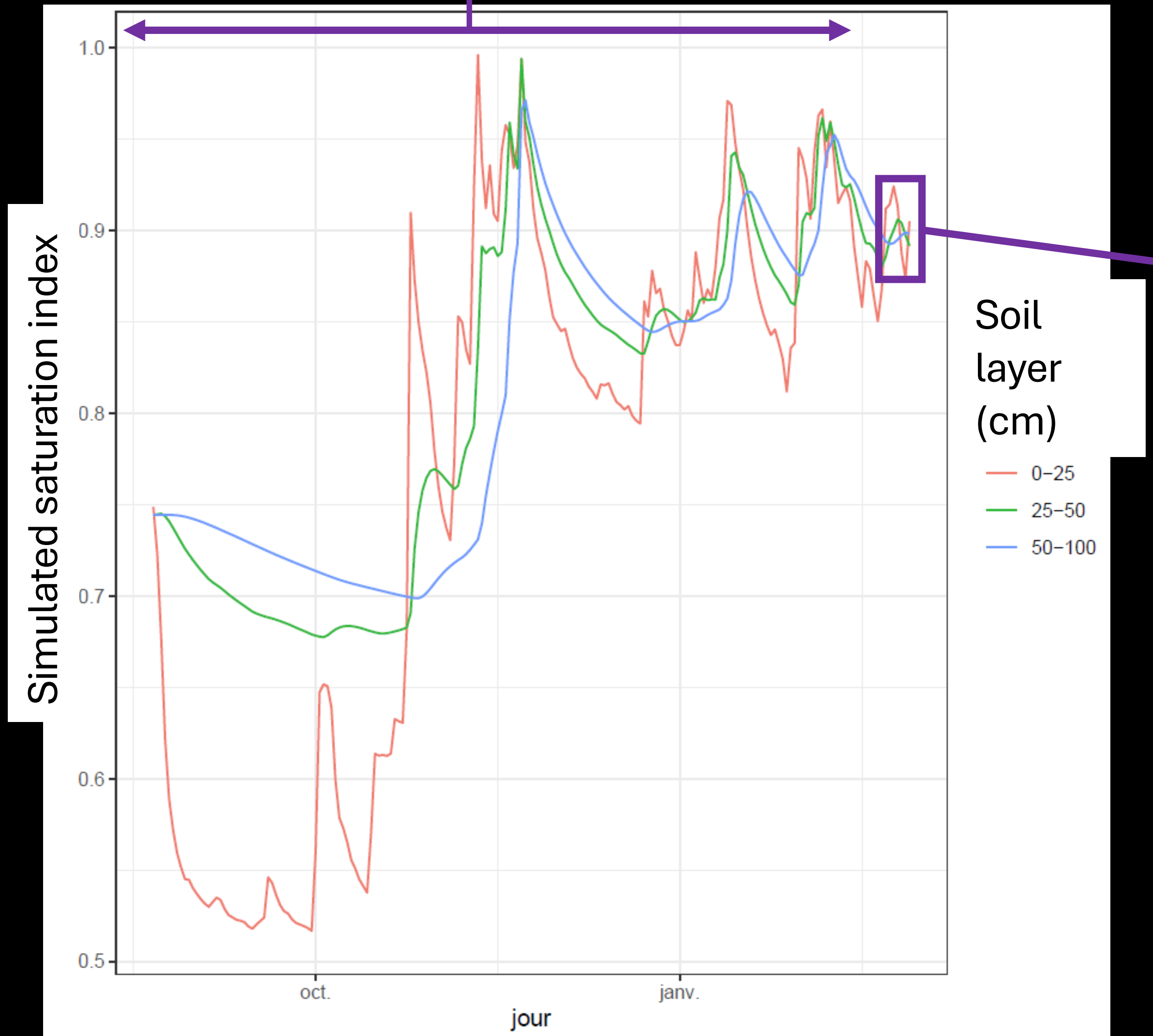
https://vsoil.hub.inrae.fr/

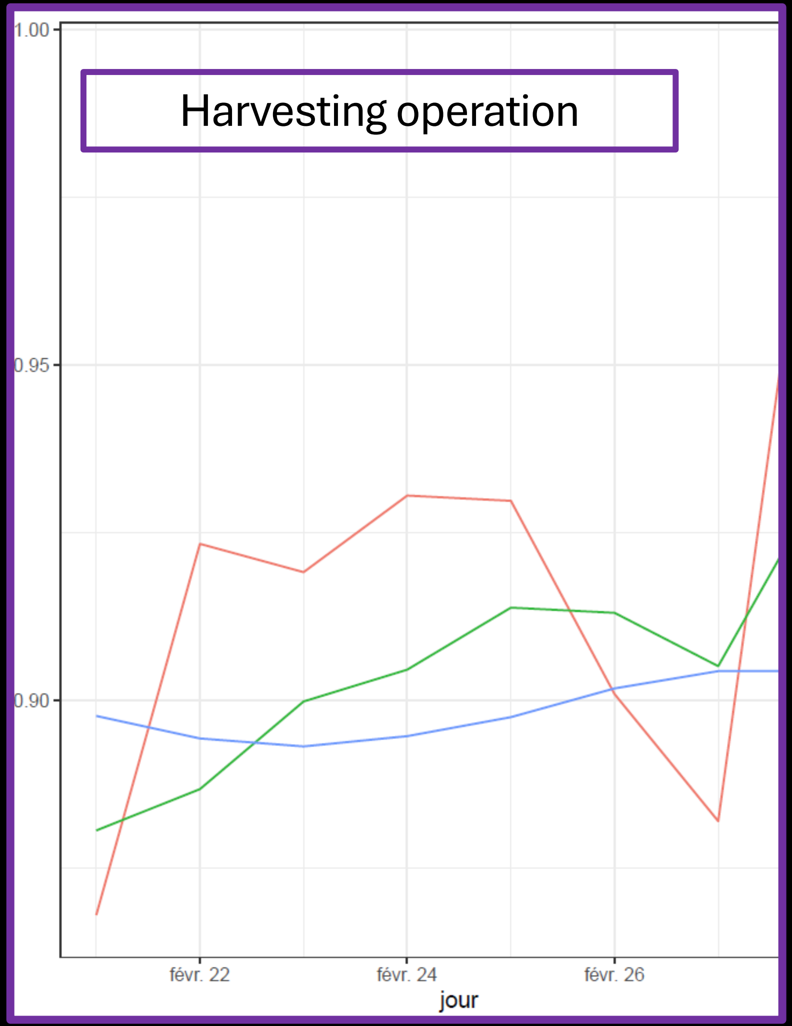


Context
Clim. service
Results

Description of the climate service

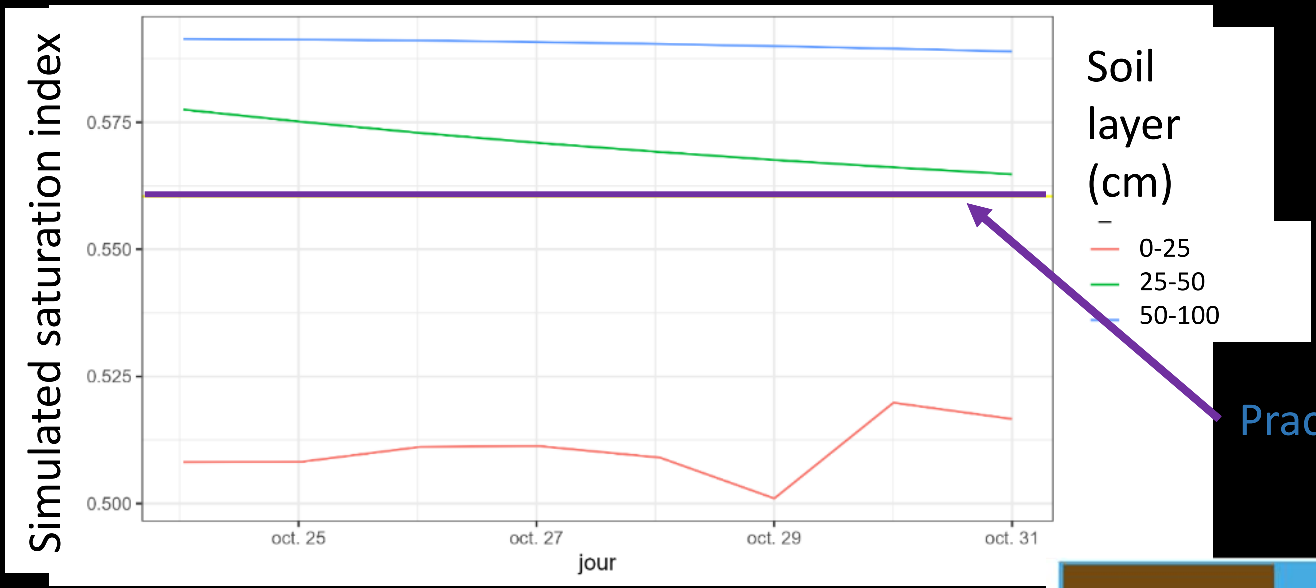
Model warming period so that users don't have to measure soil water content at the beginning of the harvesting operation





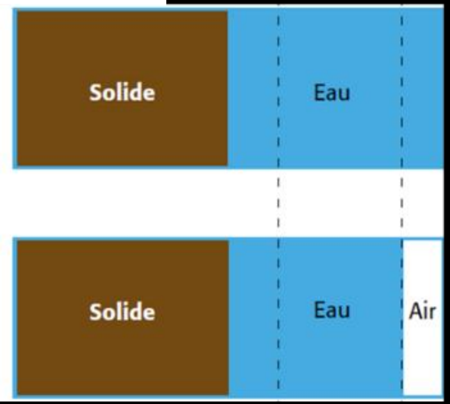
Description of the climate service

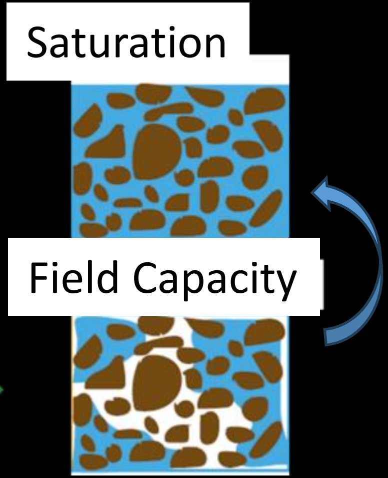
Model's outputs: Saturation index, number of practicable days, soil drying slope



Number of practicable days:
0-25cm : 8 days /8
25-50cm : 0/8
50-100cm : 0/8

Practicability threshold :





rutting ++ (Startsev et McNabb, 2000, Labelle et al. 2022 …)

- $I_{sat}(t) = \frac{H(t)}{H_{sat}}$
- $Threshold_{practicability} = \frac{H_{cc}}{H_{sat}}$
- $\Delta_{des}(t) = \frac{H(t) - H(t-3)}{3}$

Water content variation over 3 dry days following a rainy period >10mm

Results

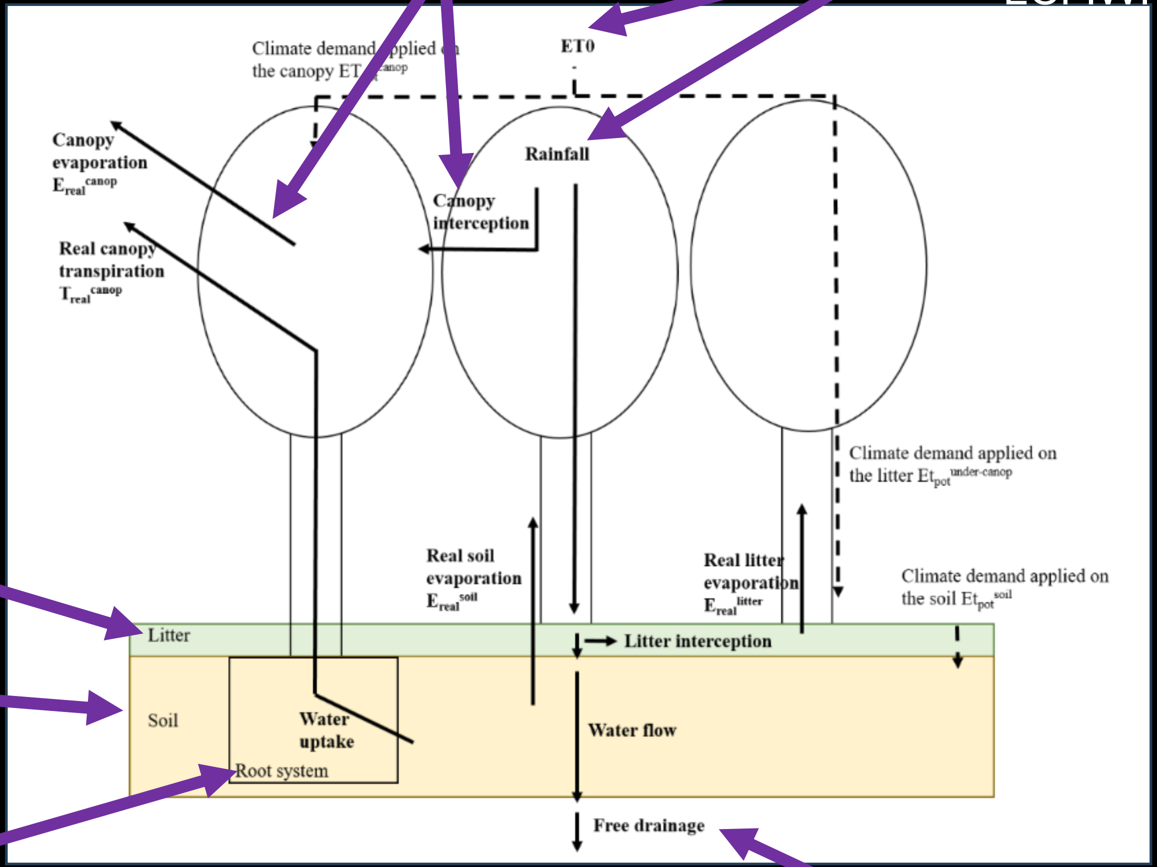
Budburst day between 90 et 130

Yellowing day between 271 et 370

LAImax between 2 et 6 m^2/m^2

Weather data source:
Local
SAFRAN
ECMWF

Sensitivity analysis of Mostafa Moradzadeh



Litter between 0 et 7cm

Texture class: medium fine, medium, coarse, fine et very fine

Epsi_root [0.2; 1]

Drainage at the profile's bottom: Ksat of the last soil horizon * 10^{-n}
n between 0 and 1

Results

Sensitivity analysis :

-Sobol method = variance-based global sensitivity analysis approach where all parameters (continuous and discrete) are changed simultaneously throughout the whole parameter space.

-Assessment of the relative contributions of each specific parameter and their interactions to the model output variance.

-Sample size of 2500

Scenarios:

(a) 01/09/2016 to 01/04/2017: $Rain_{cum}$ = 400 (LOCAL, ECMWF) or 500 mm (SAFRAN). Small cumulated rainfall between end of November and end of January.

(b) 01/09/2017 to 01/04/2018 : $Rain_{cum}$ = 600 (LOCAL) or 800 mm (SAFRAN, ECMWF). Small cumulated rainfall between end of January and end of March.

(c) 01/04/2016 to 01/04/2017: $Rain_{cum}$ = 900 (LOCAL, ECMWF) or 1100 mm (SAFRAN).

(d) 01/04/2017 to 01/04/2018 $Rain_{cum}$ = 950 (LOCAL), 1050 (ECMWF) or 1100 mm (SAFRAN).

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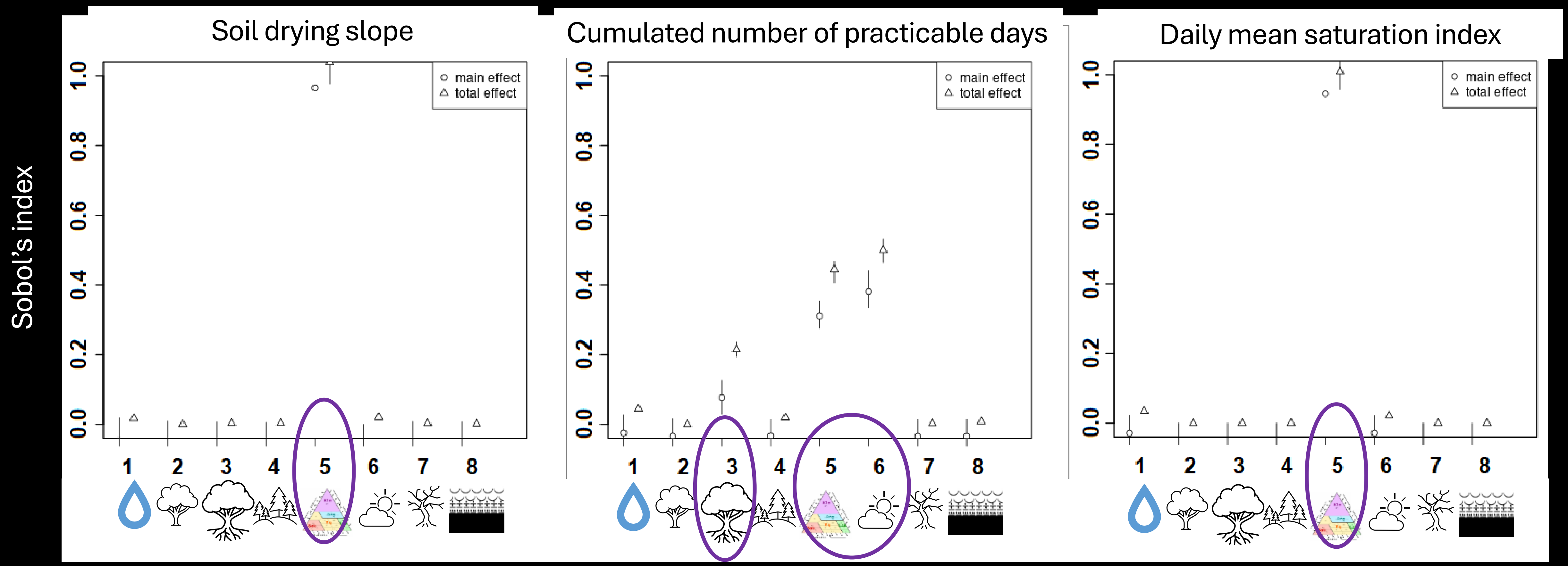
Results

0-25cm soil layer

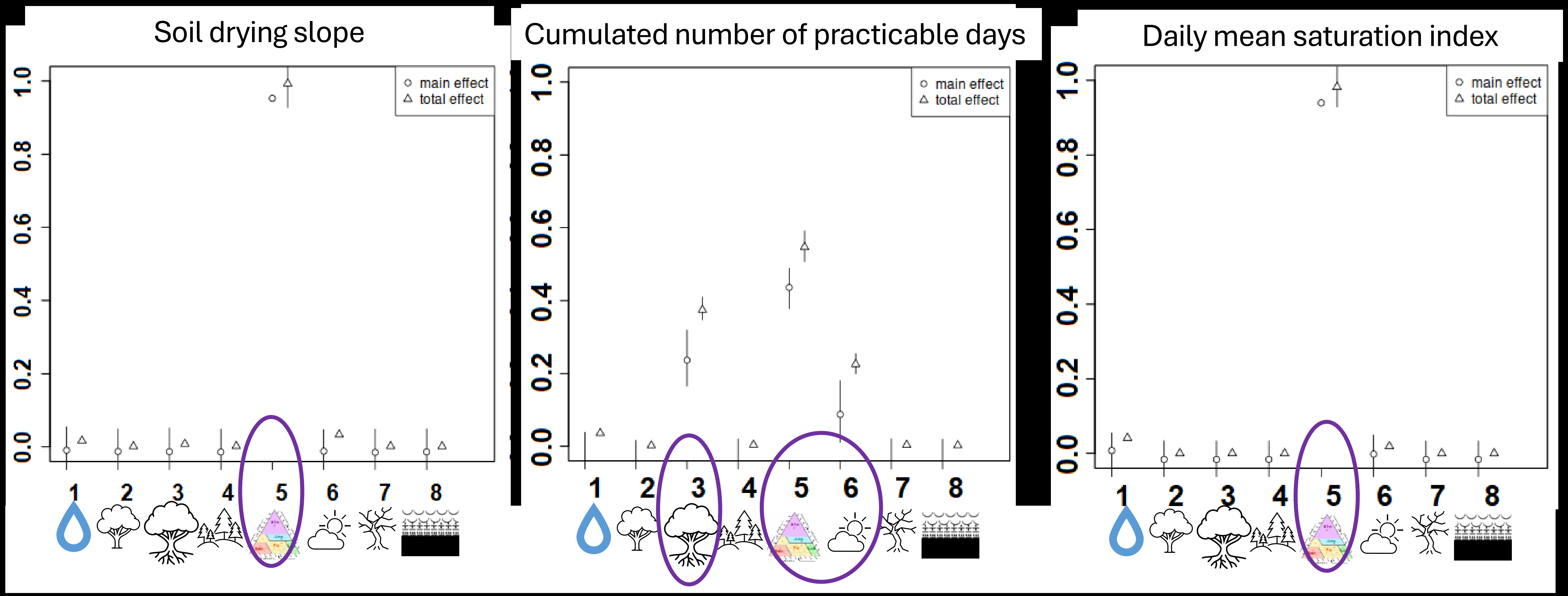


scenario (a) a = 01/09/2016 – 01/04/2017

Results

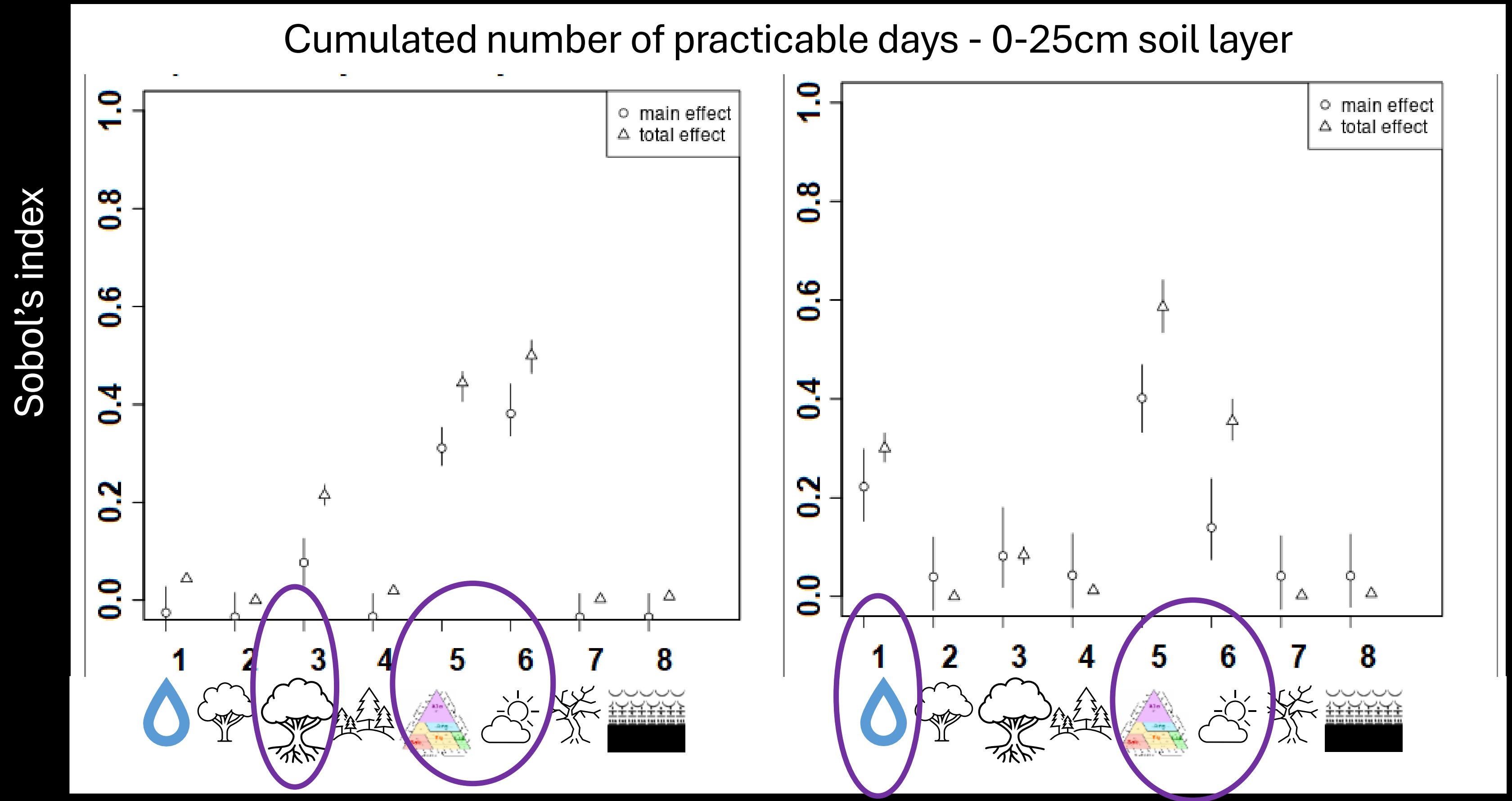
0-25cm soil layer

Sobol's index



scenario (c) c = 01/04/2016 - 01/04/2017

Results



Scenario a (dry winter, warming period = 1 month)

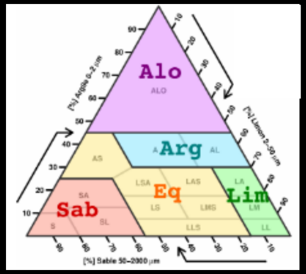
Scenario b (wet winter, warming period = 1 month)

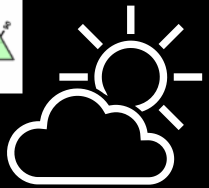
a = 01/09/2016 – 01/04/2017

b = 01/09/2017 to 01/04/2018

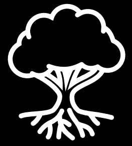
Results

Importance of input's parameters :



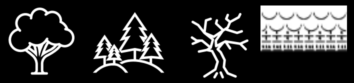


importance decreases when warming period increases



Low importance for epsi_root <0,8

importance high cum. rainfall > low cum. rainfall

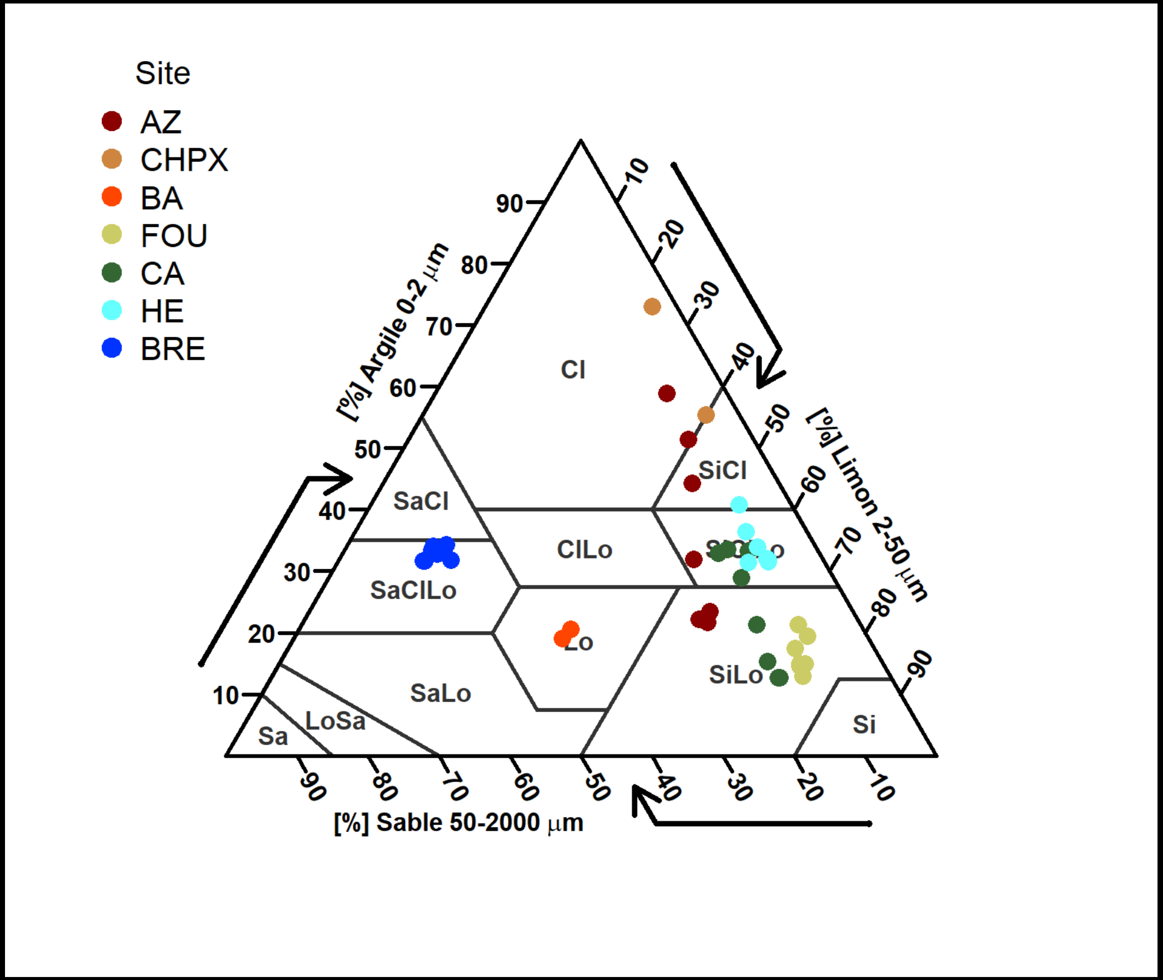


Very low importance of LAI, litter, budburst and yellowing dates

Results

Model simplification: work of Manon Martin

Experimental sites with monitoring of soil water content:



Context
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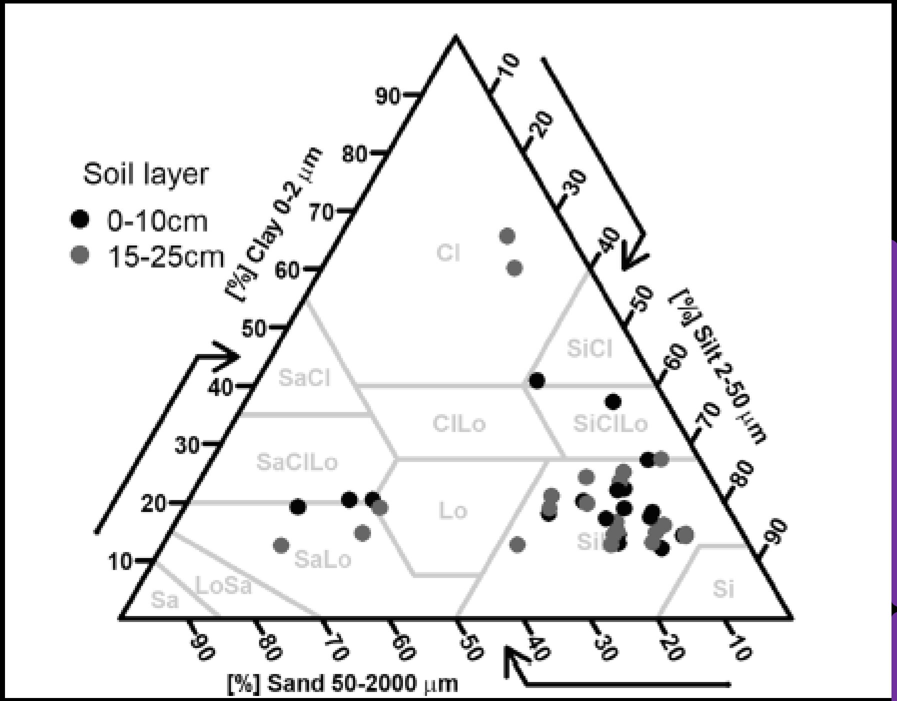
Results

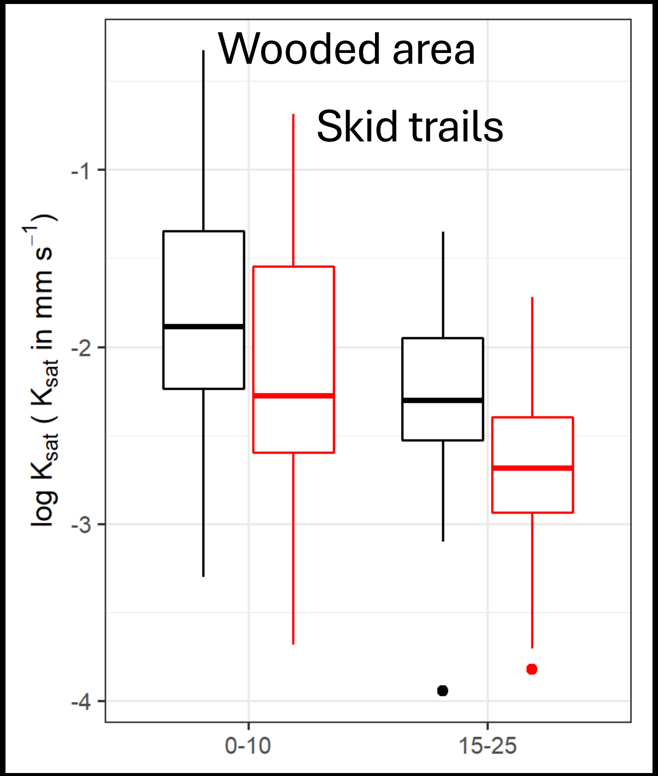
	Inputs	Outputs
Estimated hydraulic properties		
BEST C/T	Field measurements of water infiltration	Ks, θs, θr, n, m, α, η
Class of PTF		
GERM	Texture class (31)	θs, θr, n, m, α, Ks, L
GERM insense	Texture class (5)	θs, θr, n, m, α, Ks, L
euPTF18	Texture class (5) + T/S	θs, θr, n, m, α, K0, L
euPTF18 insense	Texture class (5) + T/S	θs, θr, n, m, α, K0, L
euPTF19	Texture class (12) + T/S	θs, θr, n, m, α, K0, L
eu1PTF19 insense	Texture class (5) + T/S	θs, θr, n, m, α, K0, L
ROS_class	Texture class (12)	θs, θr, n, m, α, Ks, K0, L
ROS_class insense	Texture class (5)	θs, θr, n, m, α, Ks, K0, L
continuous PTF		
EUPTF1	Particle size distribution + depth	θs, θr, n, m, α, K0, L
EUPTF1 insense	Texture class (5) + depth	θs, θr, n, m, α, K0, L
EUPTF2	Particle size distribution + depth + OM	θs, θr, n, m, α, K0, L
ROS1_neural	Particle size distribution	θs, θr, n, m, α, Ks, K0, L
ROS1_neural insense	Texture class (5)	θs, θr, n, m, α, Ks, K0, L
ROS2_neural	Particle size distribution + BD	θs, θr, n, m, α, Ks, K0, L

RMSE 0-60 cm soil layer :

	Number of practicable days	soil drying slope	Saturation index	Winter saturation index
Estimated hydraulic properties				
BEST C/T	0.222/0.101	0.038/0.044	0.248/ 0.187	0.224/0.144
Class of PTF				
GERM	0.250	0.017	0.164	0.161
GERM insense	0.241	0.015	0.156	0.157
euPTF18	0.217	0.018	0.170	0.179
euPTF18 insense	0.309	0.018	0.197	0.193
euPTF19	0.204	0.017	0.172	0.179
eu1PTF19 insense	0.220	0.017	0.177	0.184
ROS_class	0.197	0.018	0.163	0.168
ROS_class insense	0.176	0.017	0.164	0.167
continuous PTF				
EUPTF1	0.352	0.019	0.198	0.205
EUPTF1 insense	0.233	0.025	0.248	0.230
EUPTF2	0.292	0.018	0.215	0.226
ROS1_neural	0.265	0.015	0.173	0.164
ROS1_neural insense	0.222	0.018	0.183	0.159
ROS2_neural	0.187	0.014	0.148	0.142

Results



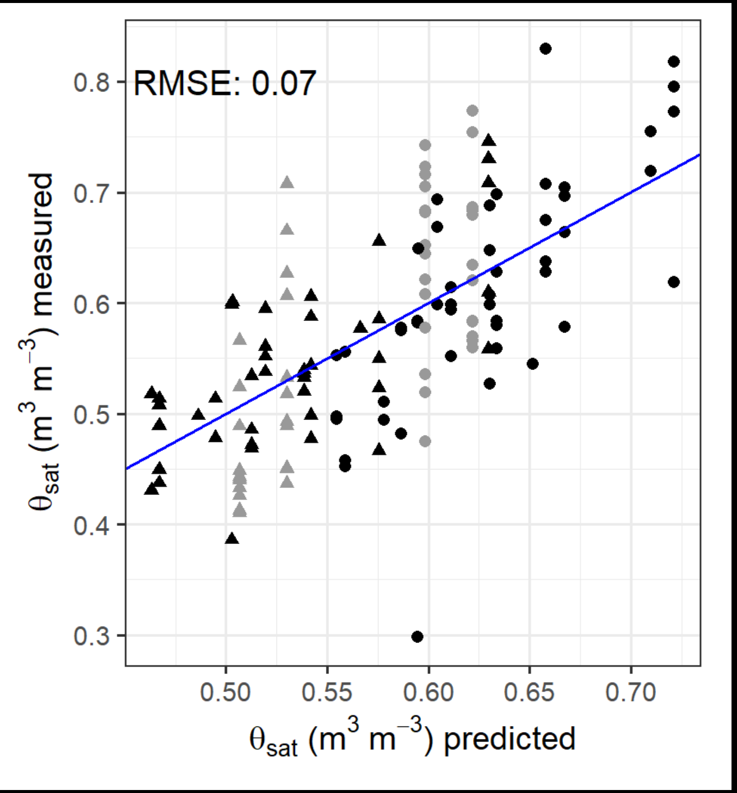


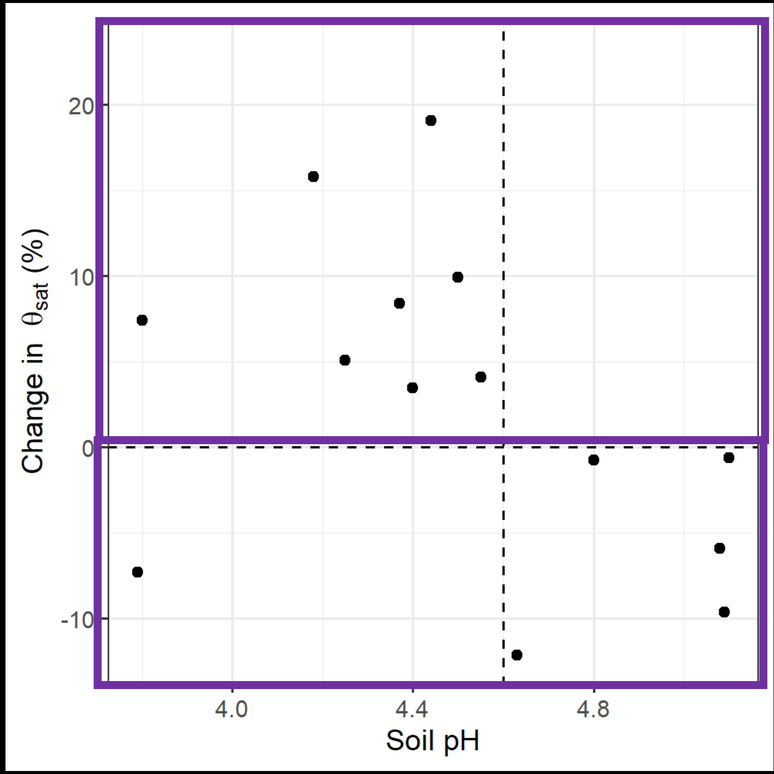
$$\theta_{sat} = \theta_{sat} - 0.05$$

$$K_{sat} = K_{sat}/2.4$$

Martin *et al. Annals of Forest Science (2024) 81:48*
https://doi.org/10.1186/s13595-024-01262-7

Results





No restoration of 0-10cm porosity

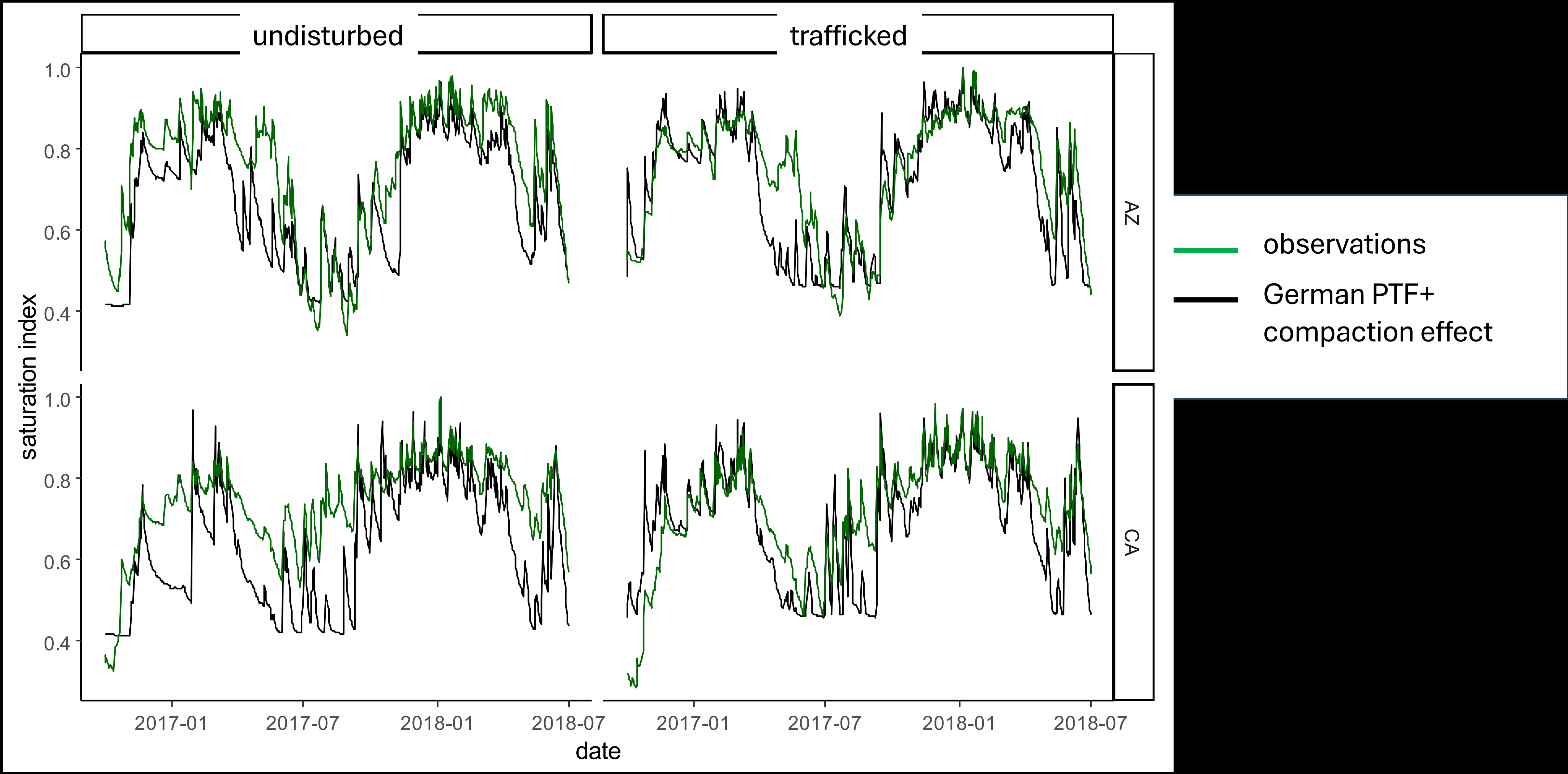
Restoration of 0-10cm porosity

Detected trend – function of soil pH but lack of data

Experimental sites, 15 years after 2 passes of a 20t forwarder

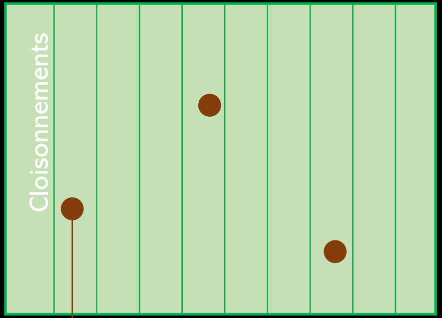
Forests where the traffic is not documented

Results


undisturbed
trafficked
AZ
CA
saturation index
1.0
0.8
0.6
0.4
2017-01
2017-07
2018-01
2018-07
date
observations
German PTF+
compaction effect

Results

Test of the prototype on real harvesting operations
Work of Emma Schmitt



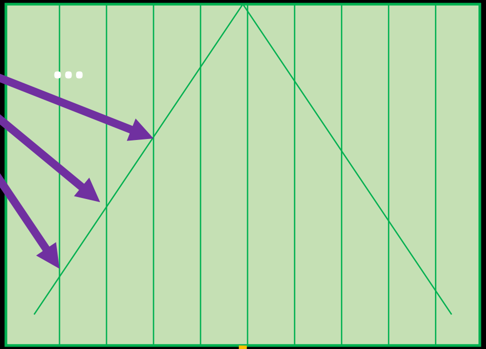
3 soil profiles :
Texture class
Horizons thickness
slope
Gravel content
Temporary water logging fetaures

LAI = 6, epsi_root (skid trails) = 0.84, Alpha_r = 0, budburst = 105, yellowing = 290

ECMWF reanalyses during operations

number of practicable days, number of practicable days/operation's duration, Mean saturation index, Max saturation index

vs.

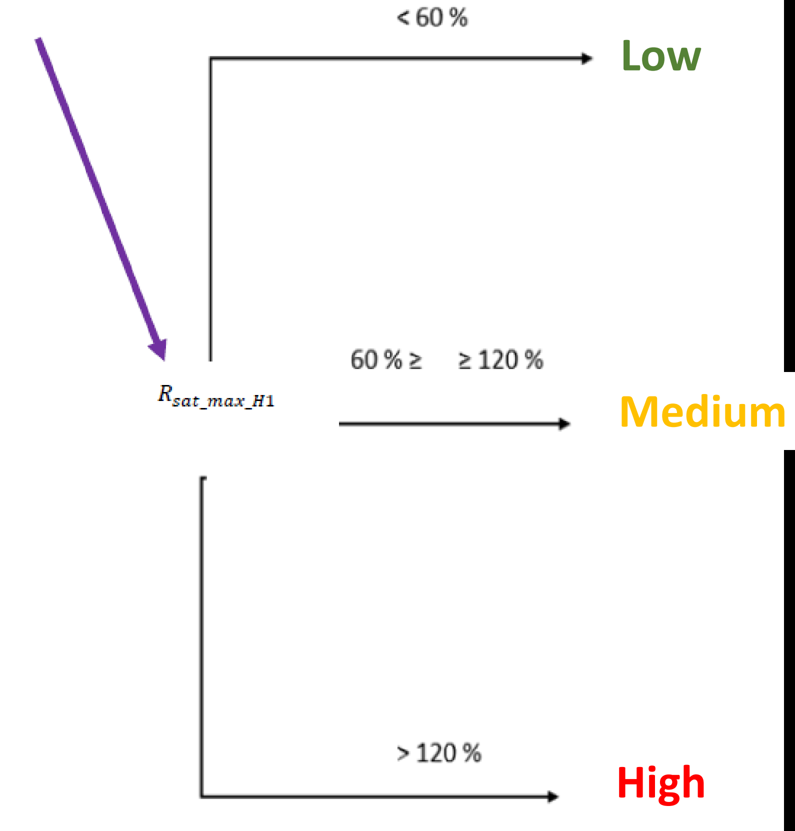


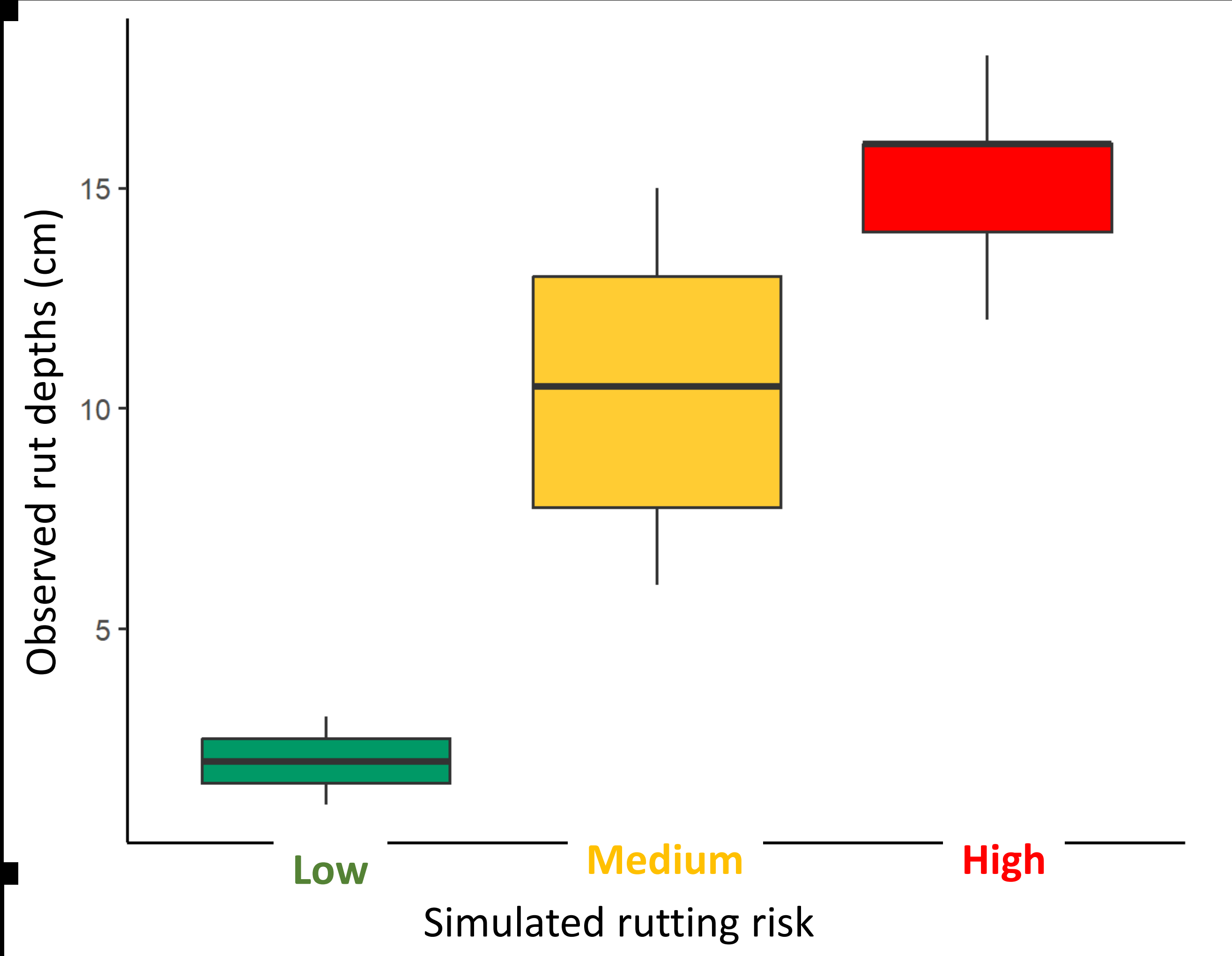
% trafficked by class of rut depth

Min., mean, max. ruts depths

Results

Max. simulated saturation index 0-25cm ÷ practicability threshold





Results

Test of the reliability of weather forecasts
Work of the Vsoil team

Texture class
Horizons thickness

When does the reliability of the weather forecasts become too low to predict the load-bearing capacity of skid trails?

Prévision ECMWF pendant chantier :

Operation's first day

observations

Weather forecasts

Stop and resume run 1

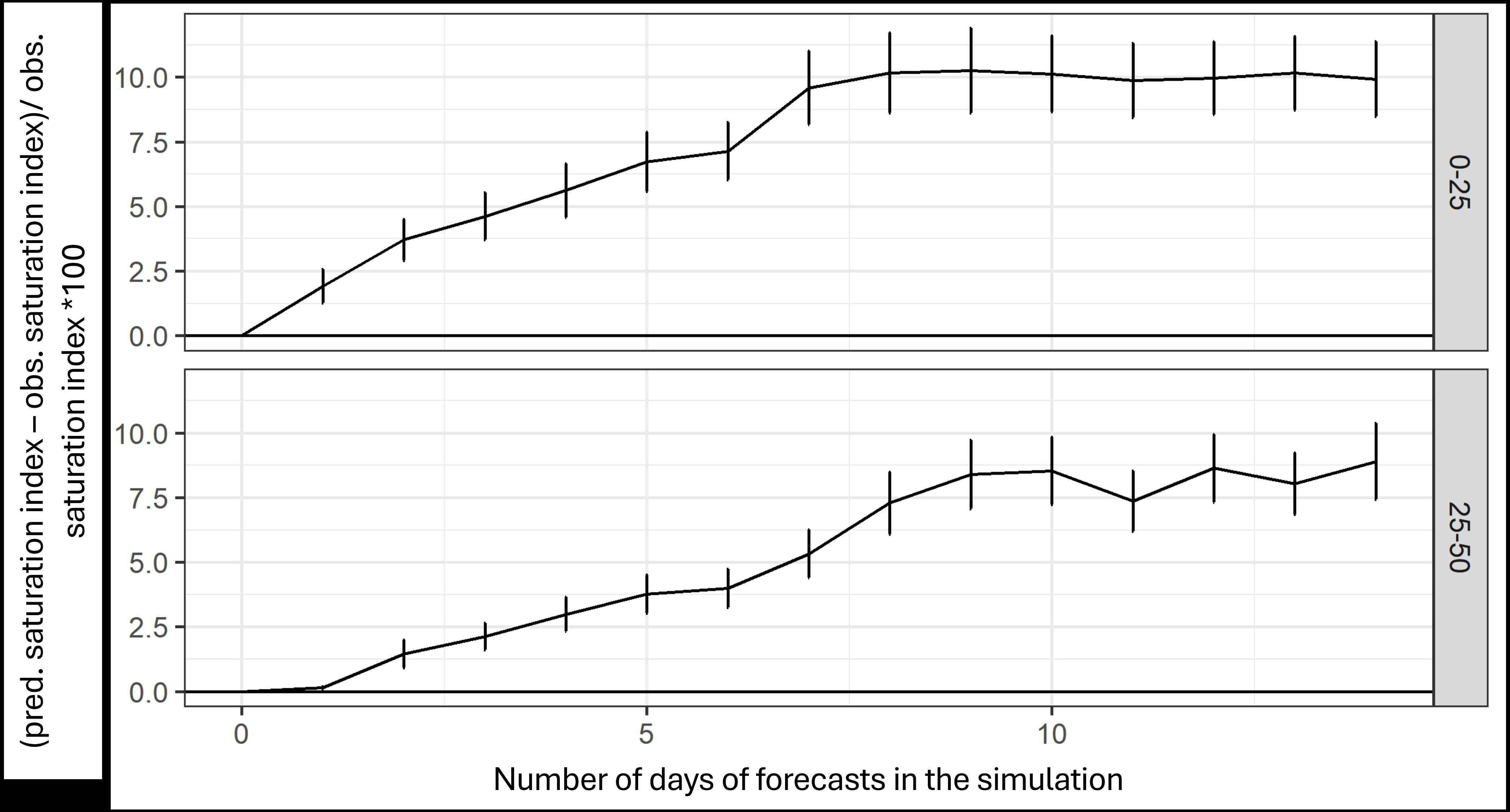
S&R 2

S&R 3

[…]

S&R 15

Results


(pred. saturation index – obs. saturation index)/ obs. saturation index *100
10.0
7.5
5.0
2.5
0.0
0-25
25-50
0
5
10
Number of days of forecasts in the simulation

Context
Clim. service
Results

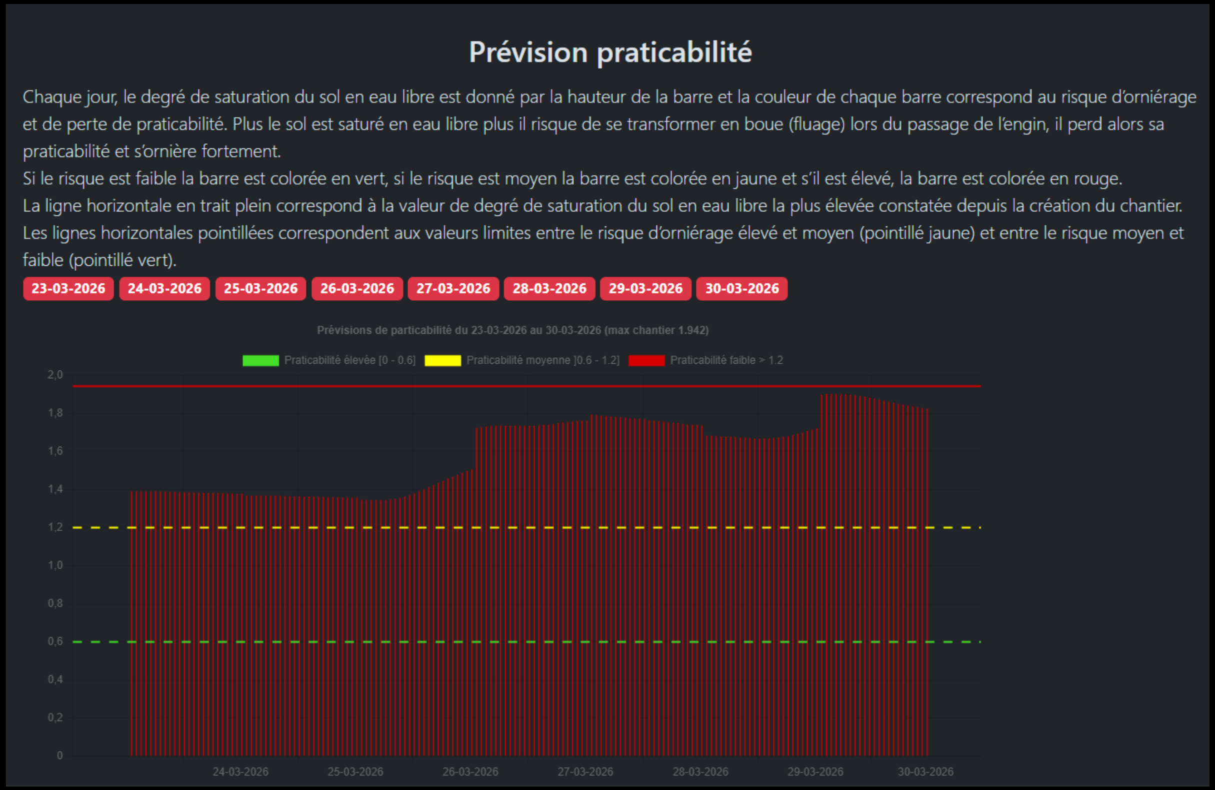
Prototype of climate service

+

- Easy to parametrize
- Reliable with ECMWF data (observations and forecasts) even if high differences between simulations when rainfalls are poorly predicted in weather forecasts

−

- Need to increase the dataset : not enough clayey sites, not enough diversity in water status during operations, not enough steep terrains, only low gravel content
- Machines features are not taken into account (models predictions were not accurate)

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Virtual Soil
Emmah

Effect of machines features on soil practicability threshold

Mobility Number (Turnage, 1972) :

$$N = \frac{Qdb}{W}\sqrt{\frac{\delta}{h}}\left(\frac{1}{1+\frac{b}{2d}}\right)$$

b = wheel width
W = wheel load
p = tire pressure
d = wheel diameter
h = side height

The lower N the higher the rut depth