Potential of the olive pickling industry greywaters for the sustainable irrigation of olive orchards. Management alternatives to reduce salinization risk

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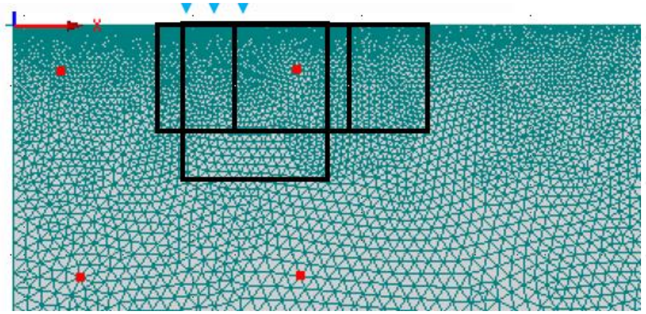
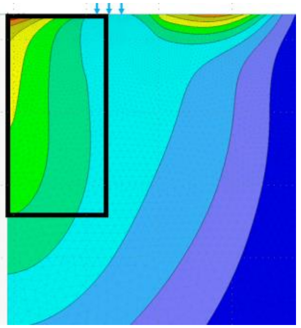
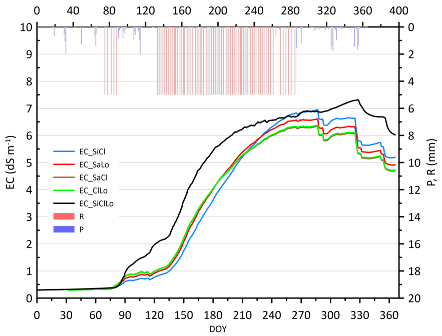
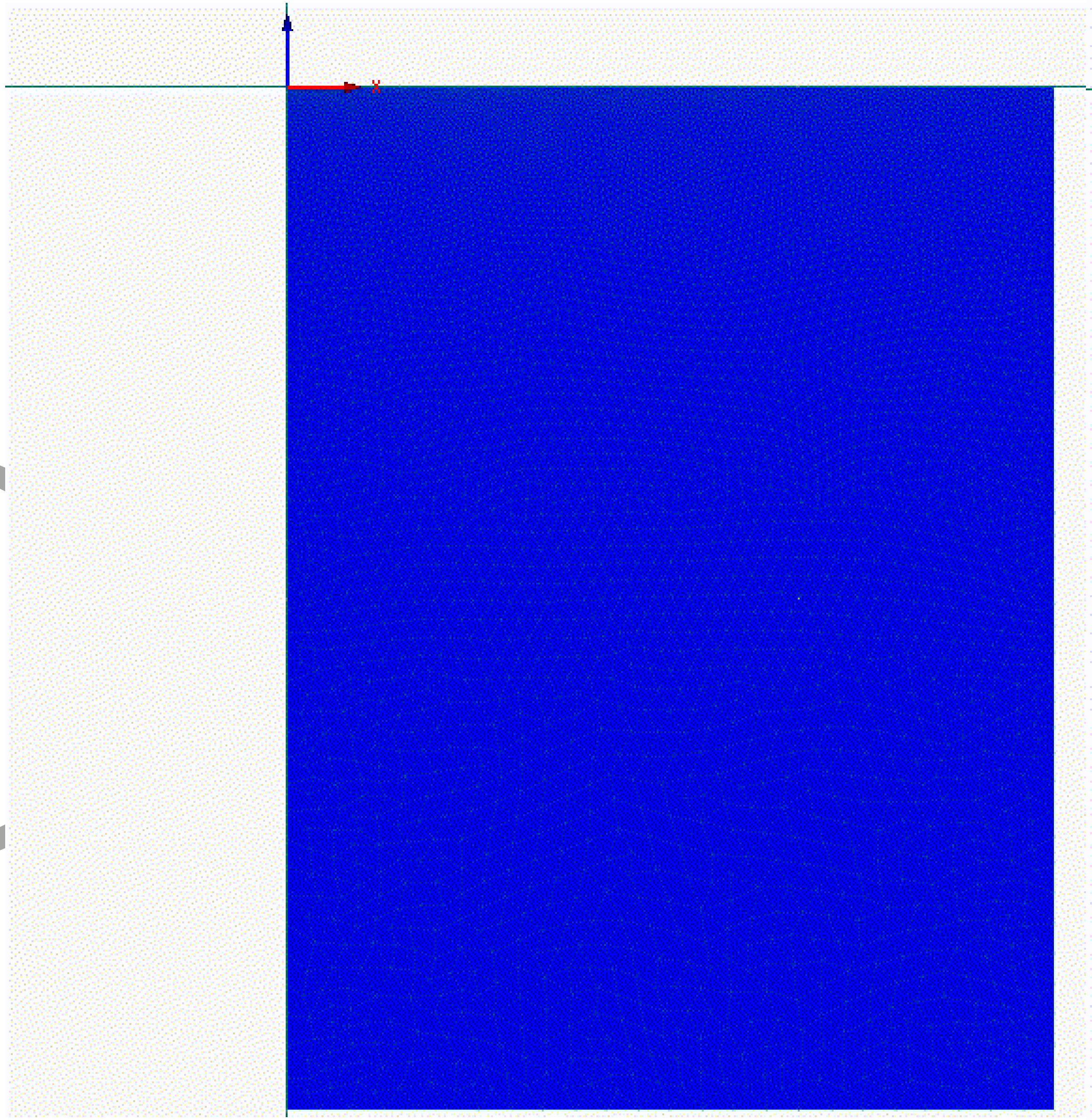
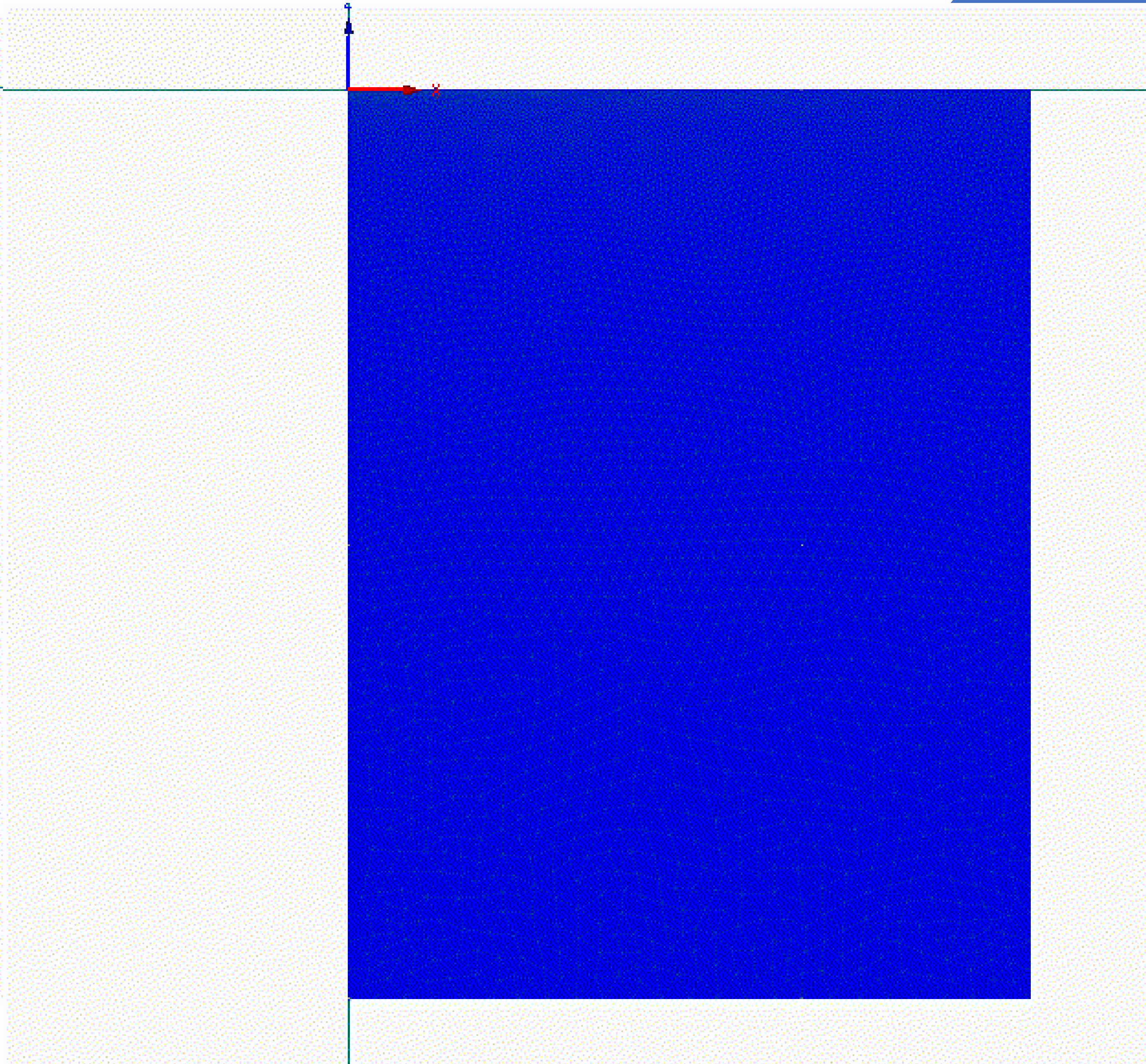






Outline

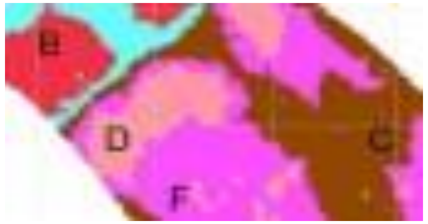



1. Introduction

Water resources availability

- World population increase -> more food needed
- FAO forecasts 50% increase in irrigated production by 2050
- 10% more water resources needed in a competitive scenario
- Water use efficieny
- Precision solutions based on:
  - Agrosystem monitorization and modelling
  - Alternative water sources
  - Reuse/recycle/reduce



Olive pickling sector in Spain

	Spain	Andalusia
Area	154. 978 ha	130. 956 ha
Production	596. 110 t	492. 919 t
Sales	1.001 – 1.132 M €	749 – 823 M €
Effluents	894.165 m^3	739.378 m^3

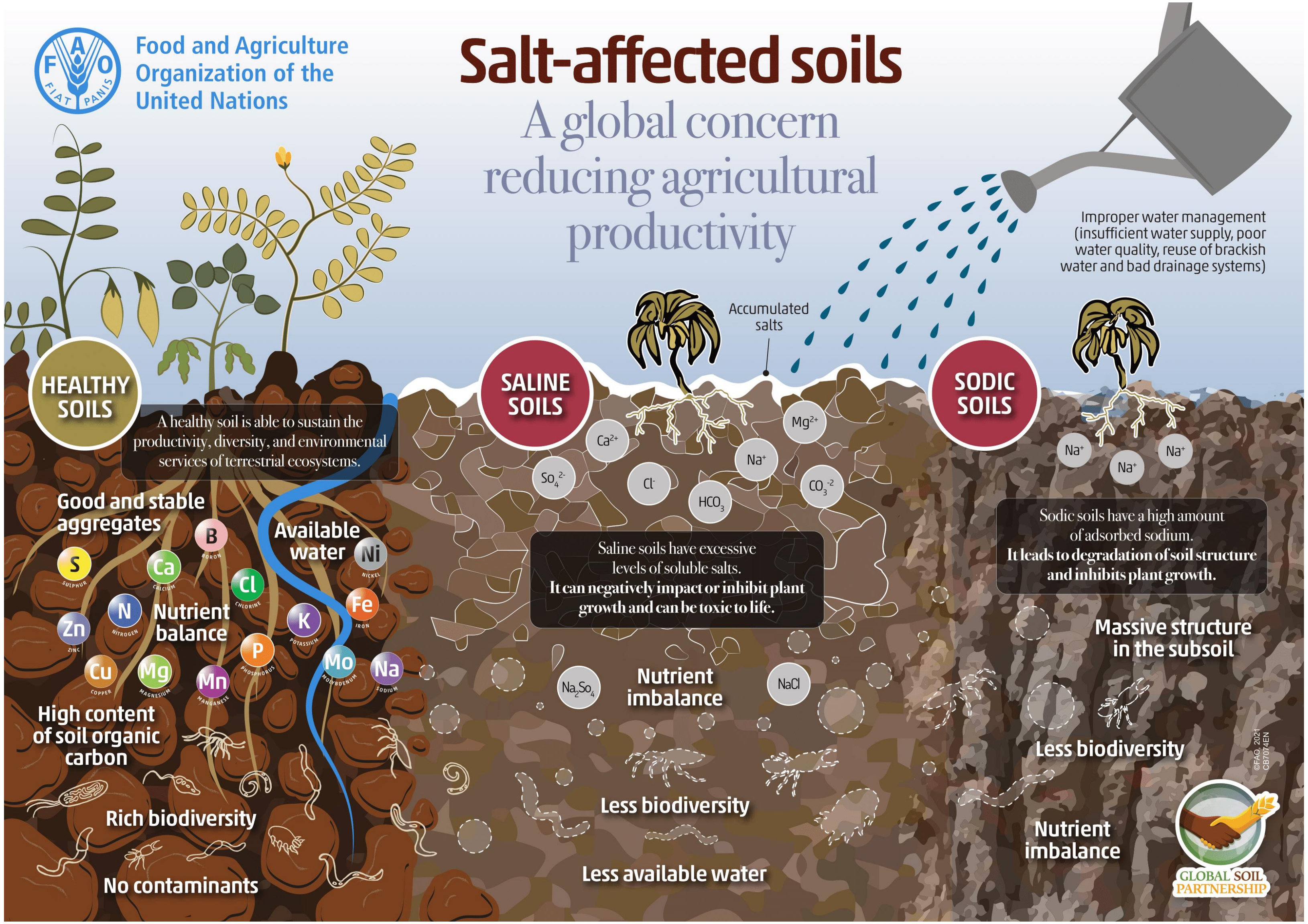
… pickling

Lots of (salty)effluents!!!!

Process of curing olives to transform oleuropein (bitter)

- **Lye-Curing** (Spanish or Californian Method). Most c… … olive production.
  1. soaking ripe olives in a lye solution (… … remove the bitterness.
  2. washed thoroughly to rem…
  3. Fermentation in a br…
  4. Possibility of o… …dium) to darken olives
- **Brine-Curing** (G… …ean Method):
  - ripe… …ne solution (salt and water) for an extended period.
- **Dry** … …tyle):
  - … olives in salt without the use of water.
- …g:
  - …ubmerging ripe olives in water and changing the water regularly to remove bitterness.

Soil salinity and sodicity



Soil salinity and sodicity

ECe, DS/M	SALINITY INTENSITY[4]	EFFECT ON CROP GROWTH[5]	ESP, %	SODICITY HAZARD
<0.75	None	None	<15	None
0.75-2	Slight	None	15-30	Slight
2-4	Moderate	Yields of sensitive crops may be restricted	30-50	Moderate
4-8	Strong	Yields of many crops are limited	50-70	High
8-15	Very strong	Only tolerant crops yield satisfactorily	>70	Extreme
>15	Extreme	Only a few very tolerant crops yield satisfactorily		

Olive trees tolerance to salts

Tolerance	Cultivar
Tolerant	Lechín de Sevilla Arbequina Picual
Moderately tolerant	Gordal sevillana Hojiblanca Manzanilla de Sevilla Koroneiki
Sensitive	Frantoio

Effects of stress on olive tree development

Step	Period	Stress effects
Vegetative growth	All season	Next season reduction of vegetation and flowering
Spring bud	Feb-Apr	Flowering reduction
Flowering	May	Abortion
Fruit formation	May-June	Next season development
Fruit development	June-harvest	Decrease in fruit size
Oil accumulation	July-harvest	Oil concentration reduction

2. Objetives

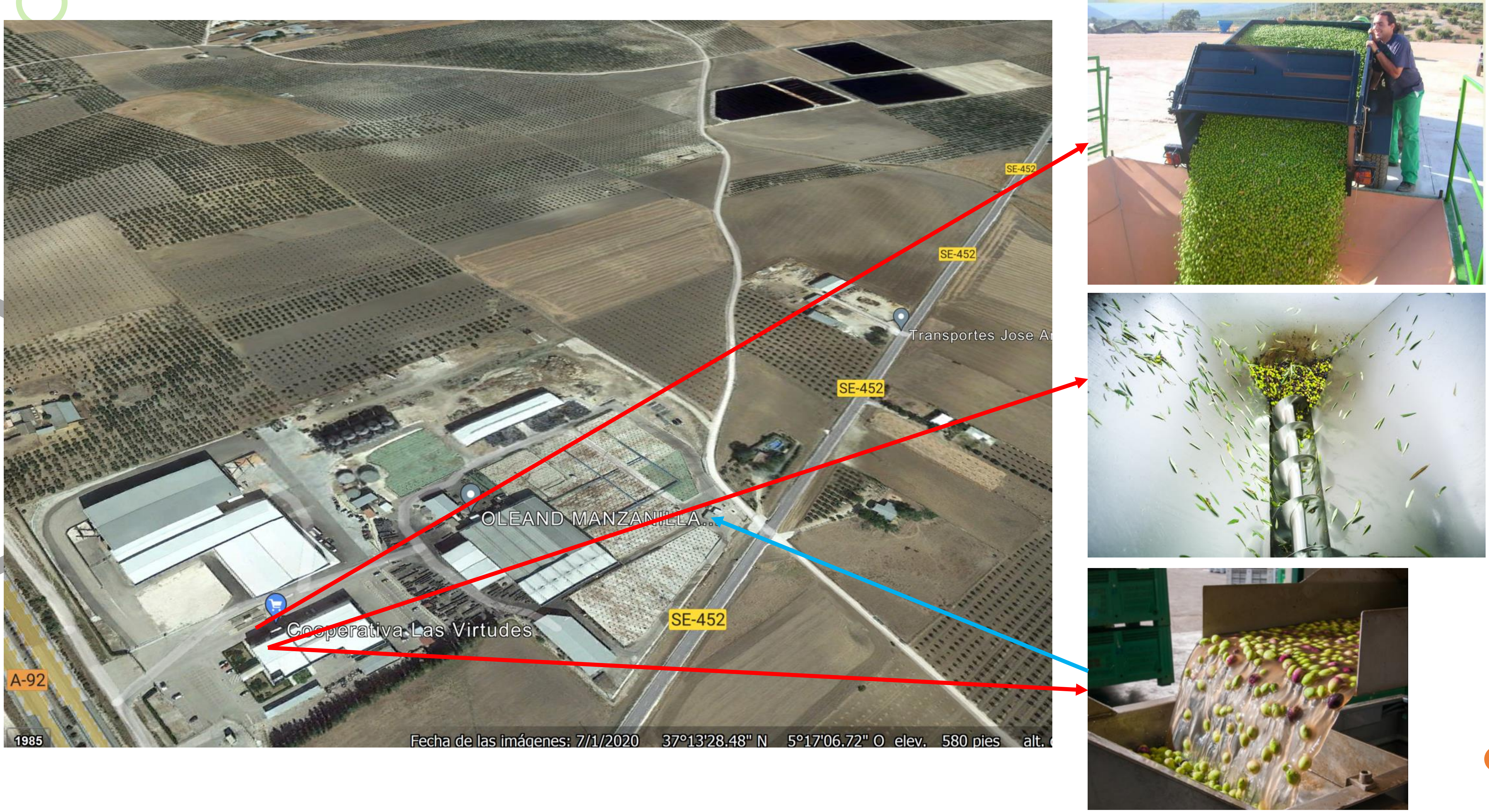
2. Objetives

- Characterize olive pickiling industry effluents (What)
- Identify the best possible places to use them (Where)
- Explore alternative irrigation management (soil textural barriers) to reduce salt concentration in the root zone (How)
- Evaluate the system in a real olive orchard

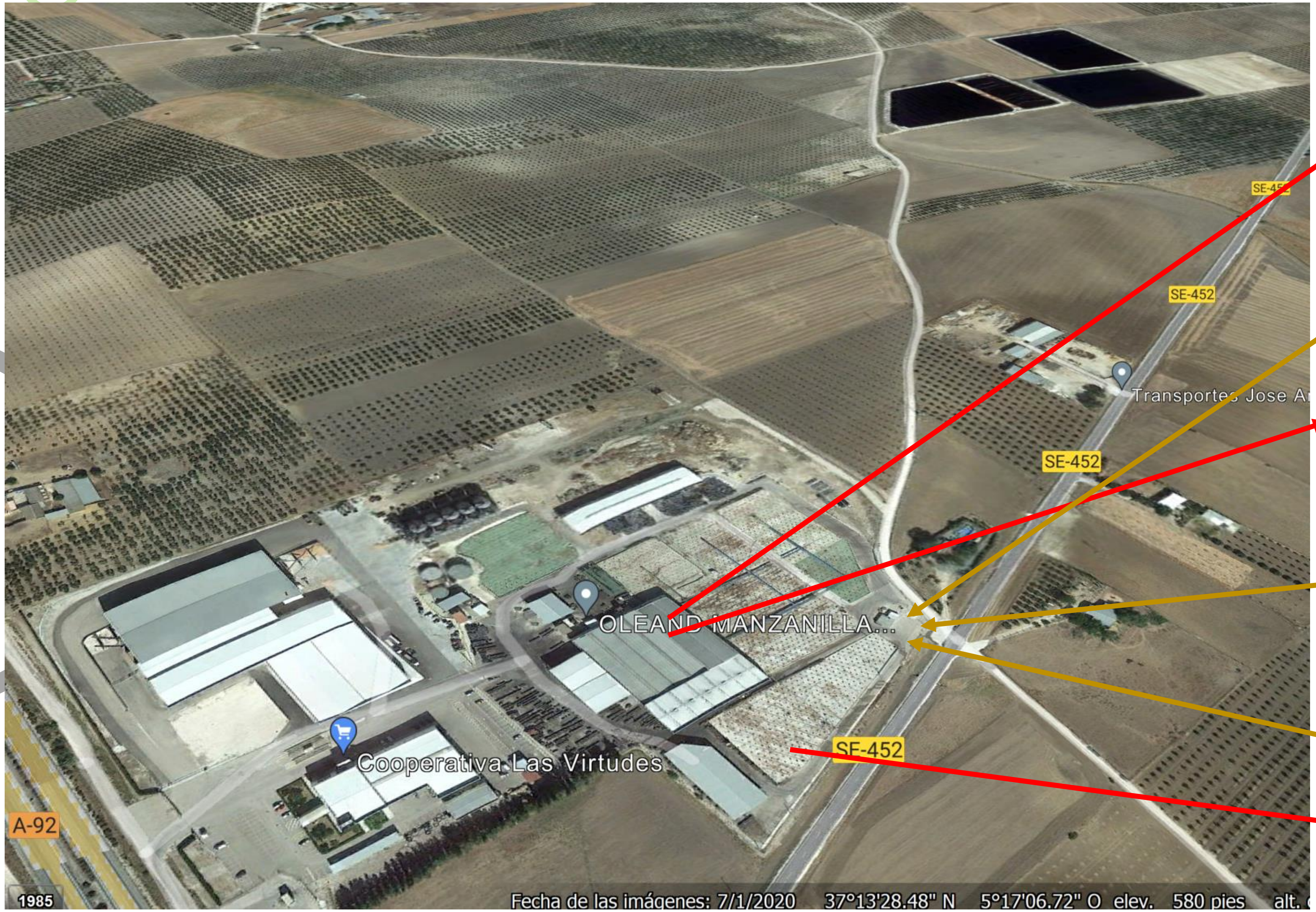
Recover and reuse additional water resources in the most posible sustainable way

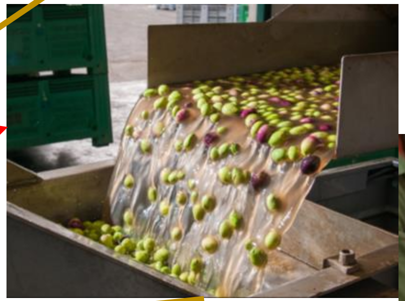
3. Industry effluents monitorization (What)

Olive pickling

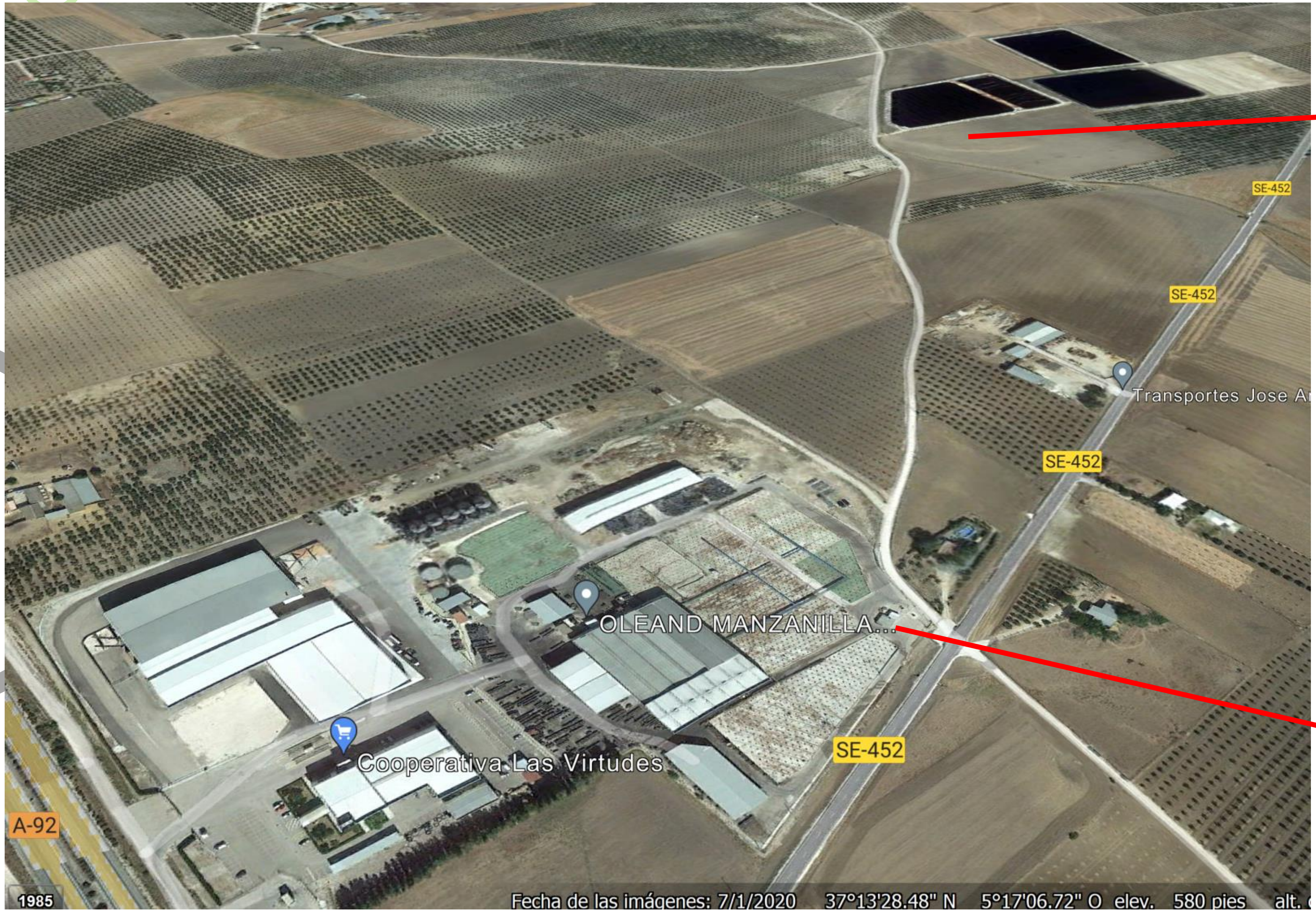


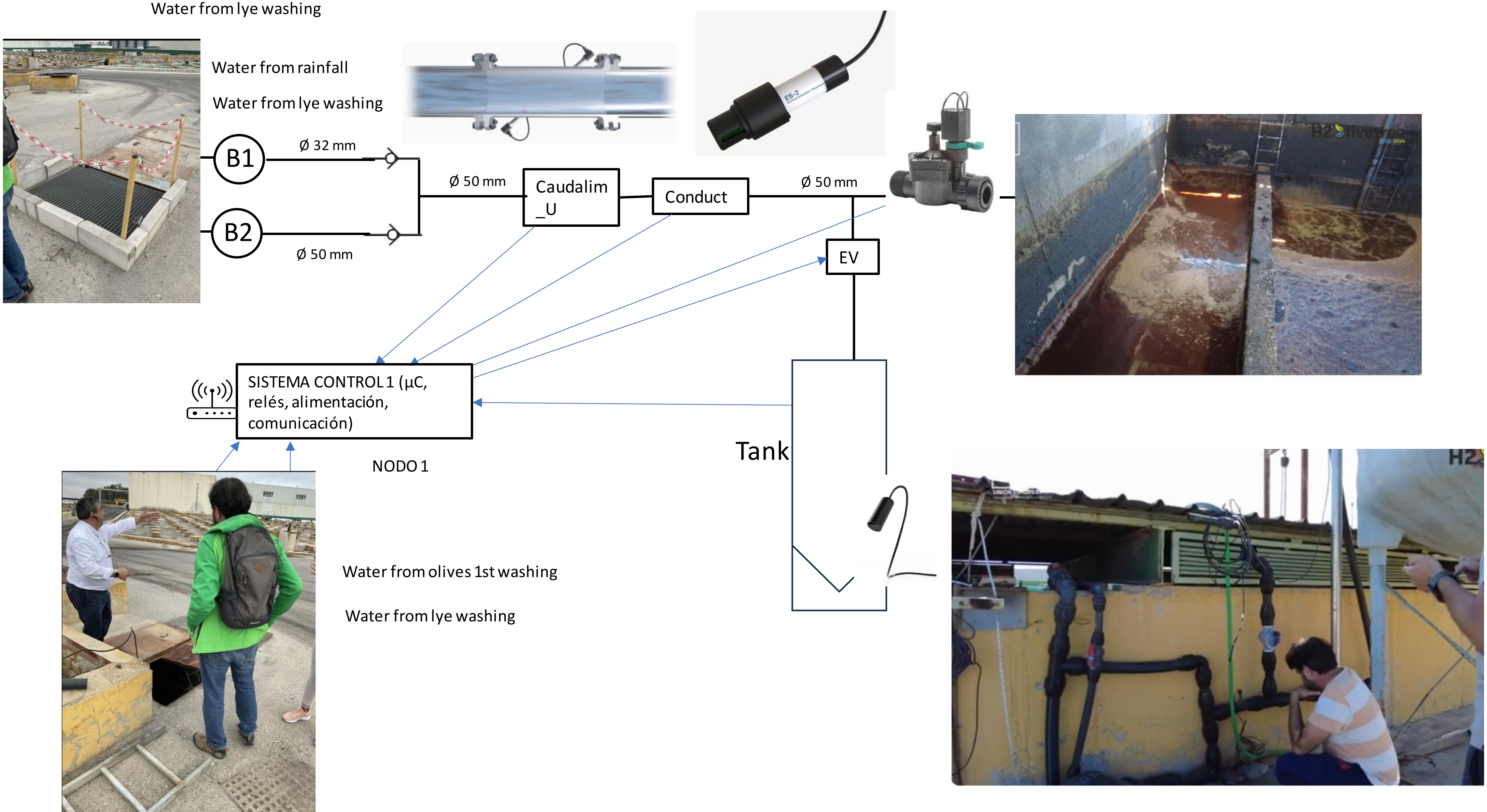
Olive pickling

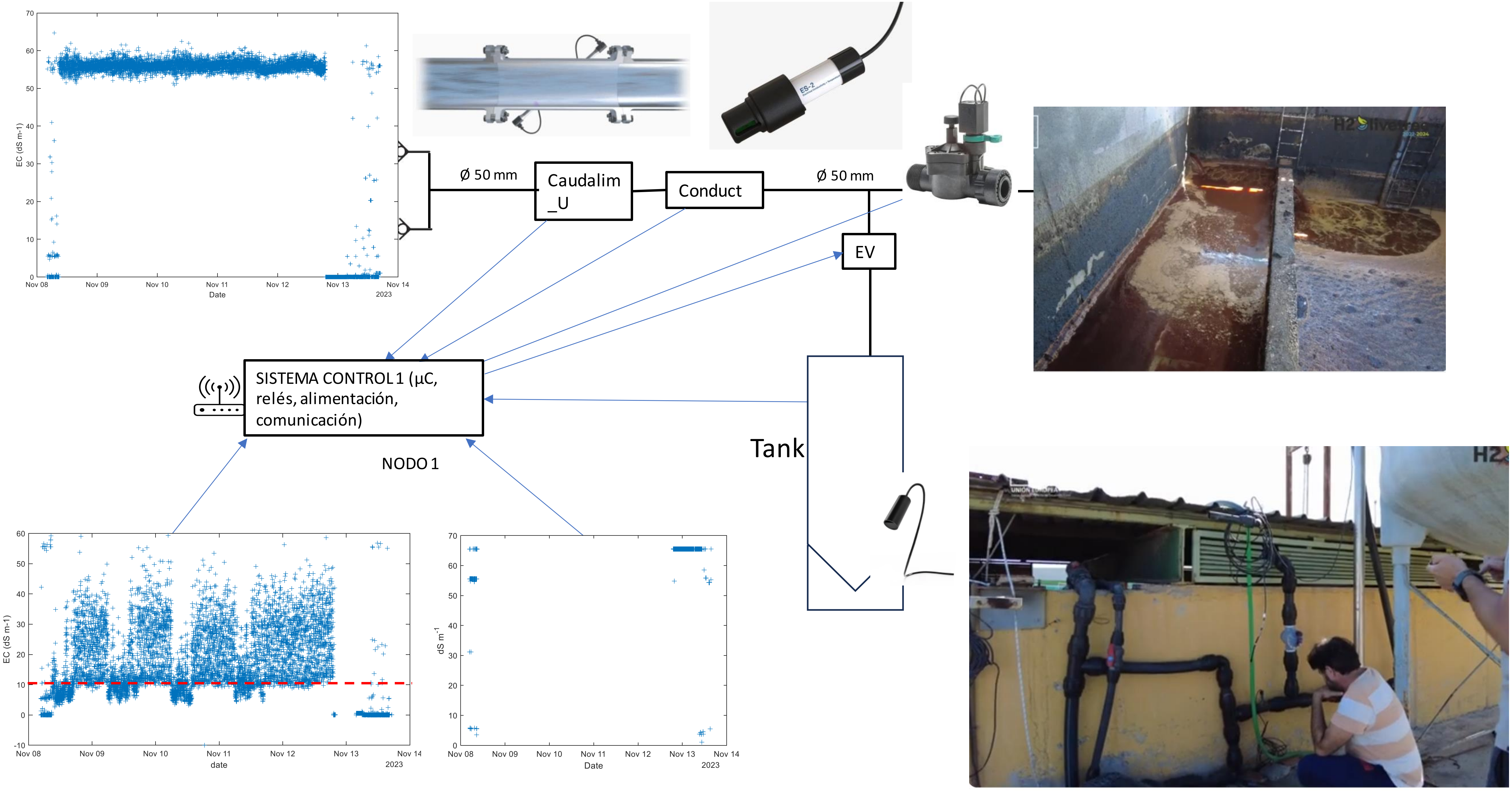




Olive pickling



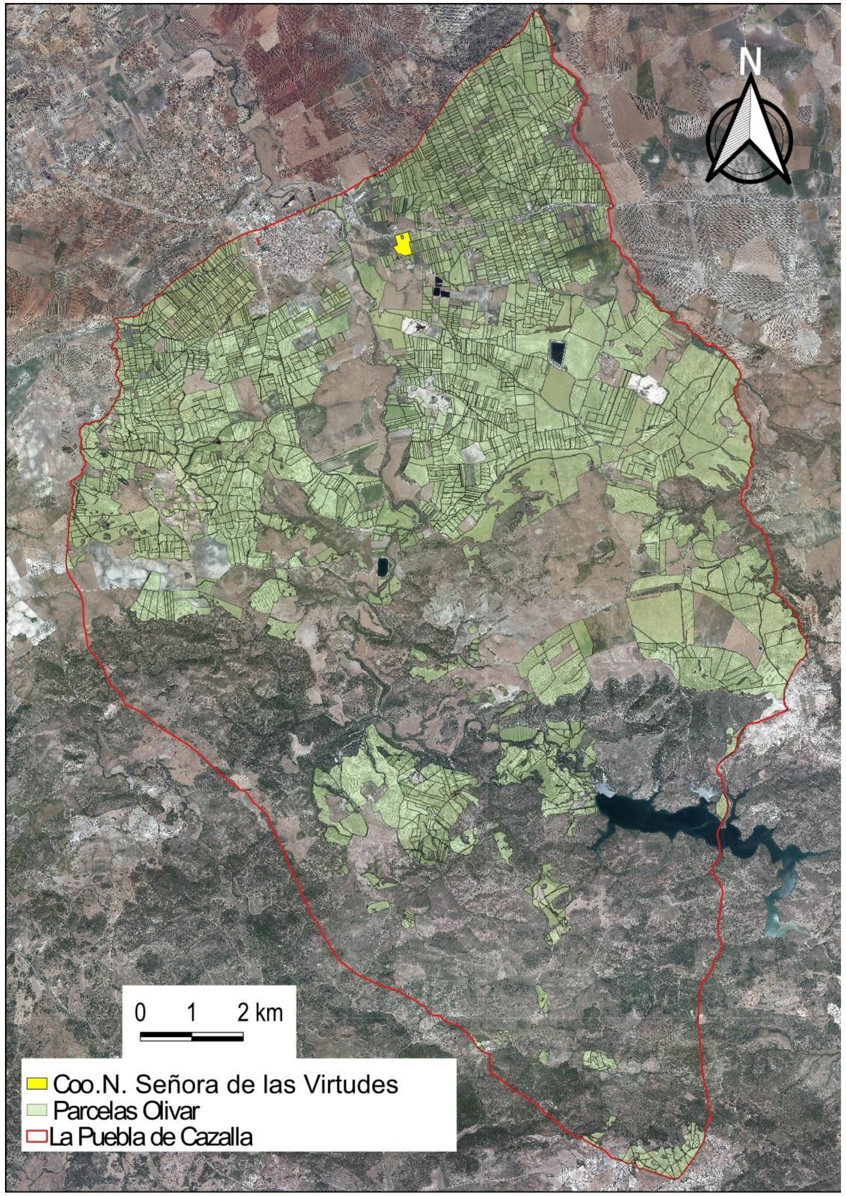

Water from lye washing
Water from rainfall
Water from lye washing
B1
Ø 32 mm
B2
Ø 50 mm
Ø 50 mm
Caudalim _U
Conduct
Ø 50 mm
EV
SISTEMA CONTROL 1 (μC, relés, alimentación, comunicación)
NODO 1
Tank
Water from olives 1st washing
Water from lye washing



EC (dS m-1)
Date
Nov 08
Nov 09
Nov 10
Nov 11
Nov 12
Nov 13
Nov 14
2023
Ø 50 mm
Caudalim _U
Conduct
Ø 50 mm
EV
SISTEMA CONTROL 1 (µC, relés, alimentación, comunicación)
NODO 1
Tank
EC (dS m-1)
date
dS m-1
Date

4. A GIS based tool to prioritize the irrigation of olive orchards with olive pickling greywaters (Where)

Location of olive orchards

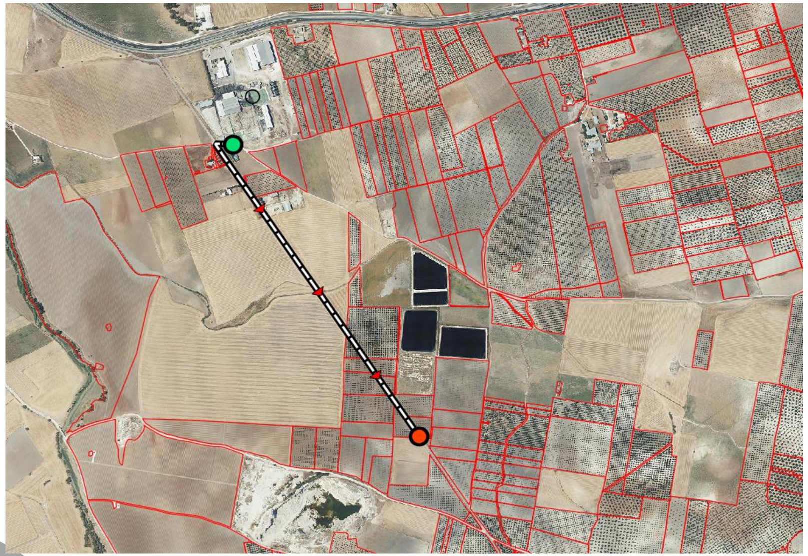


GIS oriented approach

Prioritization as a weighted average dependent on:

- Distance to the industry (D)
- Soil type (T)
- Irrigation Water availability (W)
- Slope (S)

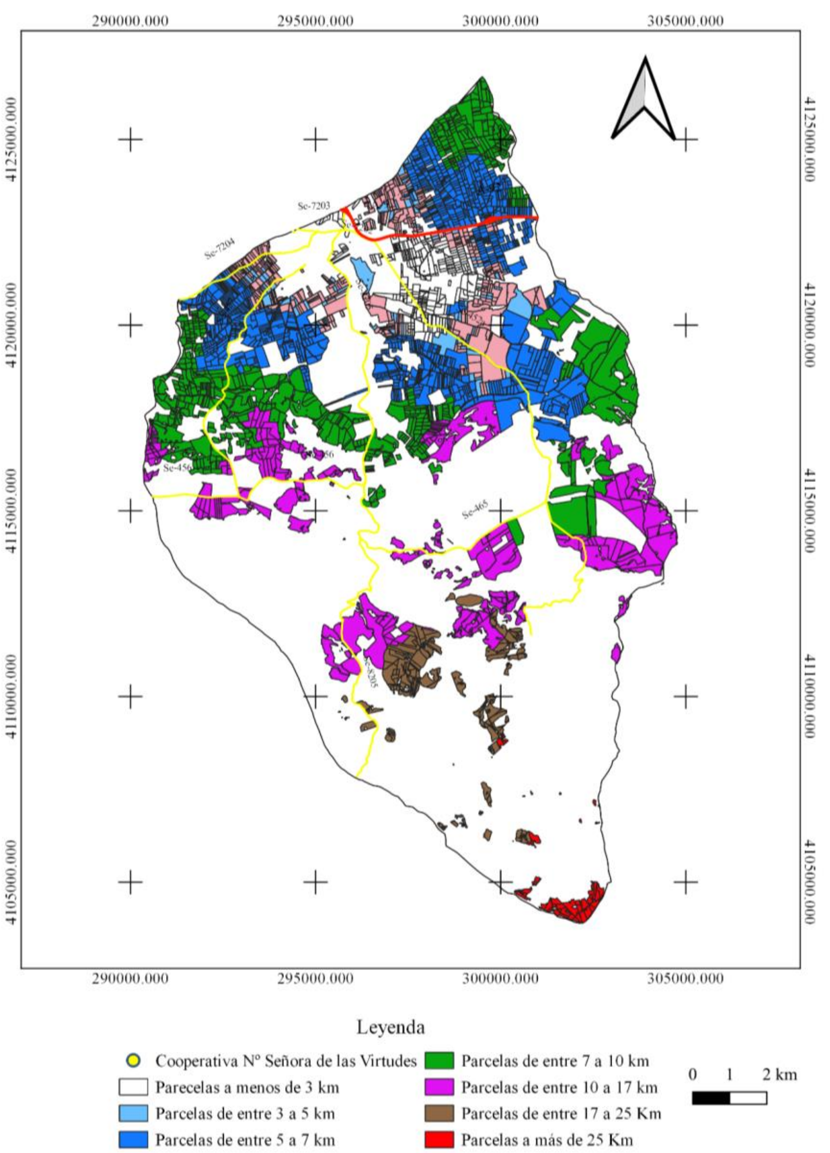
Priority index. Distances from the industry



Qgis plugin *Online Routing Mapper*

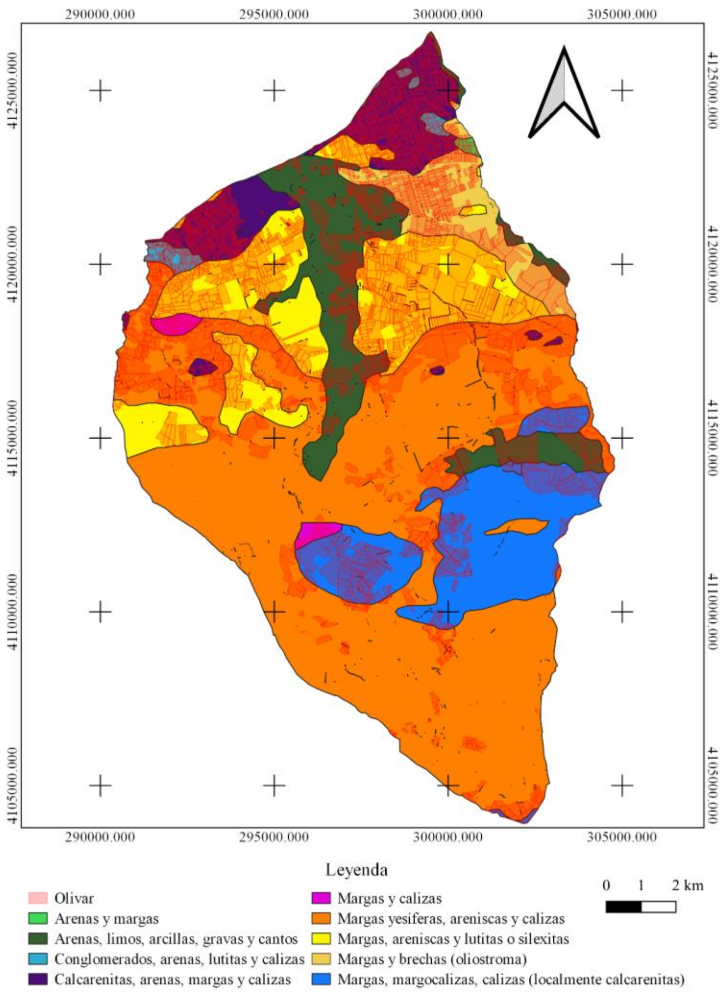
Distance (km)	Score
< 3 km	2
3 < d < 5	1.75
5 < d < 7	1.5
7 < d < 10	1.25
10 < d < 17	1
17 < d < 25	0.5
d > 25	0

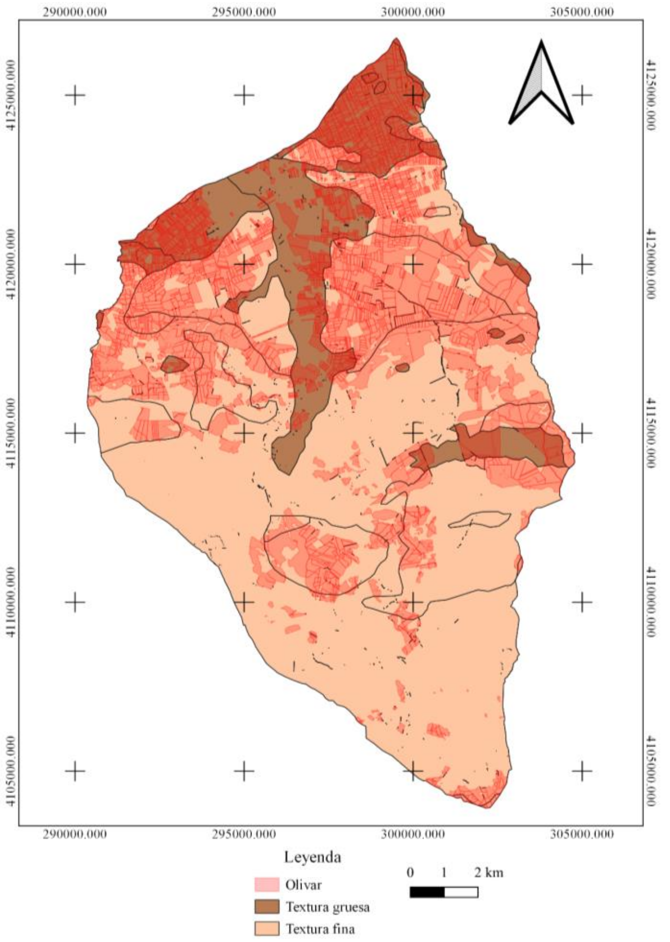
$$I = \mathbf{0.5D} + f_2 T + f_3 W + f_4 S$$



Priority index. Soil type

Soil Texture (T)	Score
Coarse	1
Fine	0.75



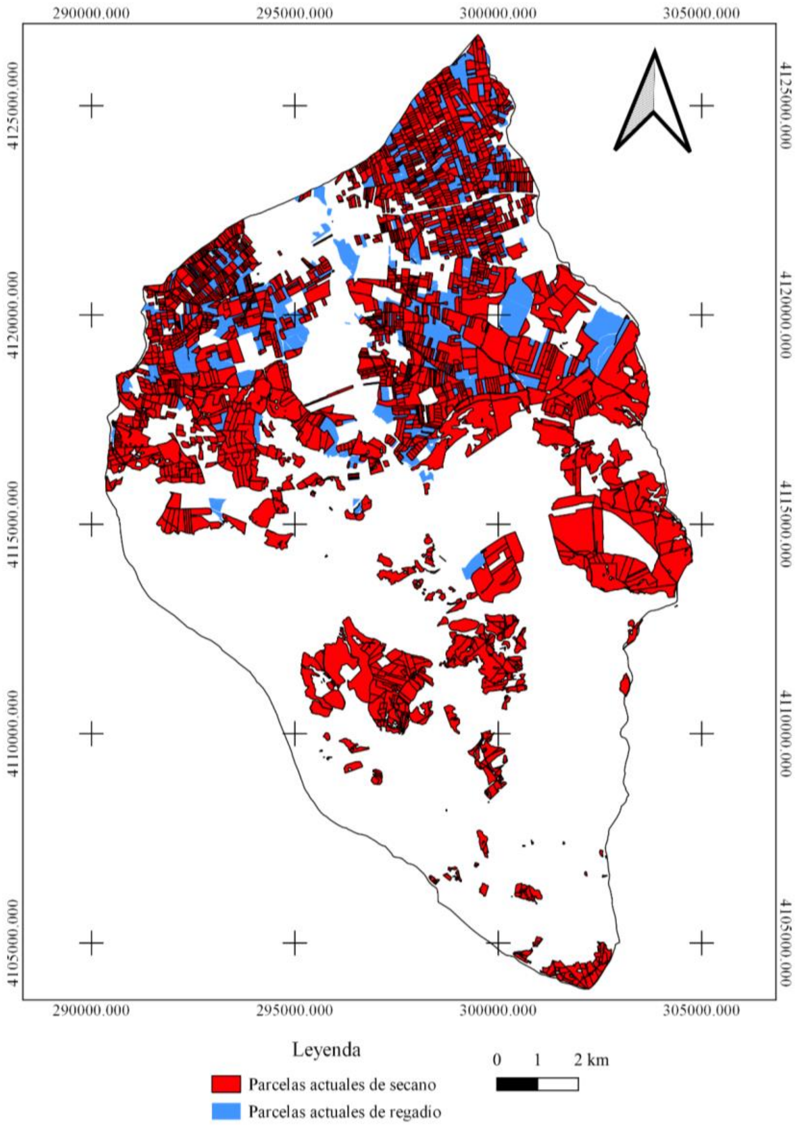


$$I = f_1 D + \mathbf{0.1T} + f_3 W + f_4 S$$

Priority index. Water availability

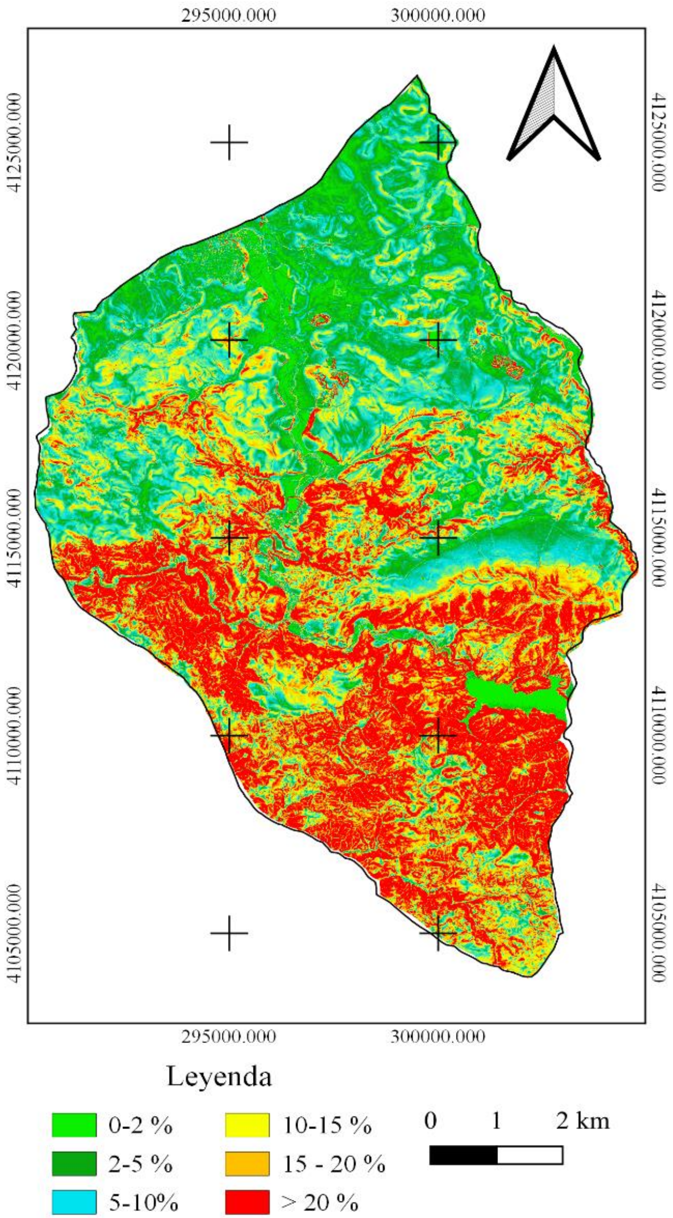
Irrigation Water Availability (W)	Score
$S_{irr} > 0.5\ S_f$	1
0.08< S ≤ 0.15	0.75
S > 0.15	0.5

$$I = f_1 D + f_2 T + \mathbf{0.3W} + f_4 S$$



Priority index. Slope

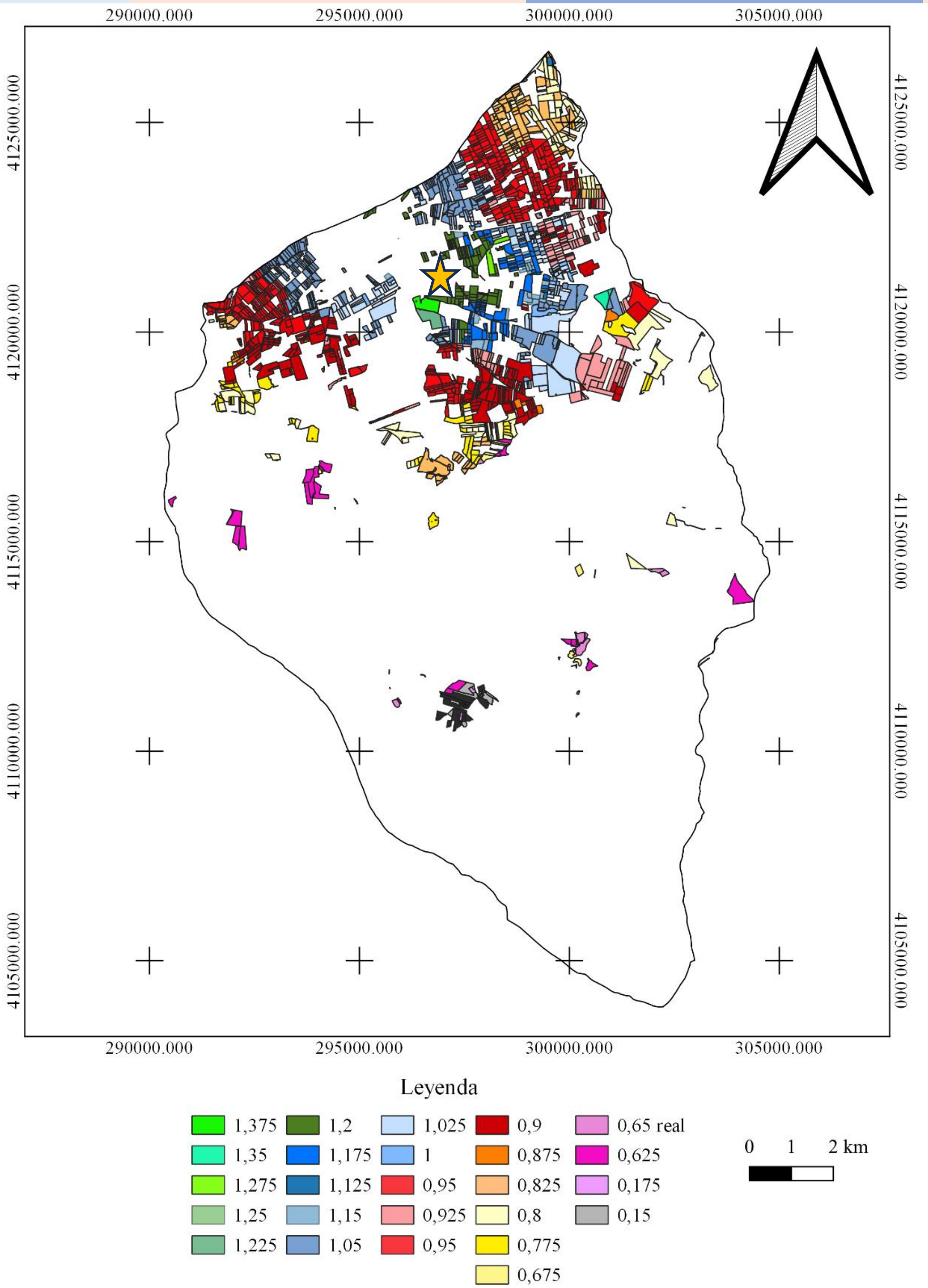
$$I = f_1 D + f_2 T + f_3 W + \mathbf{0.1} S$$

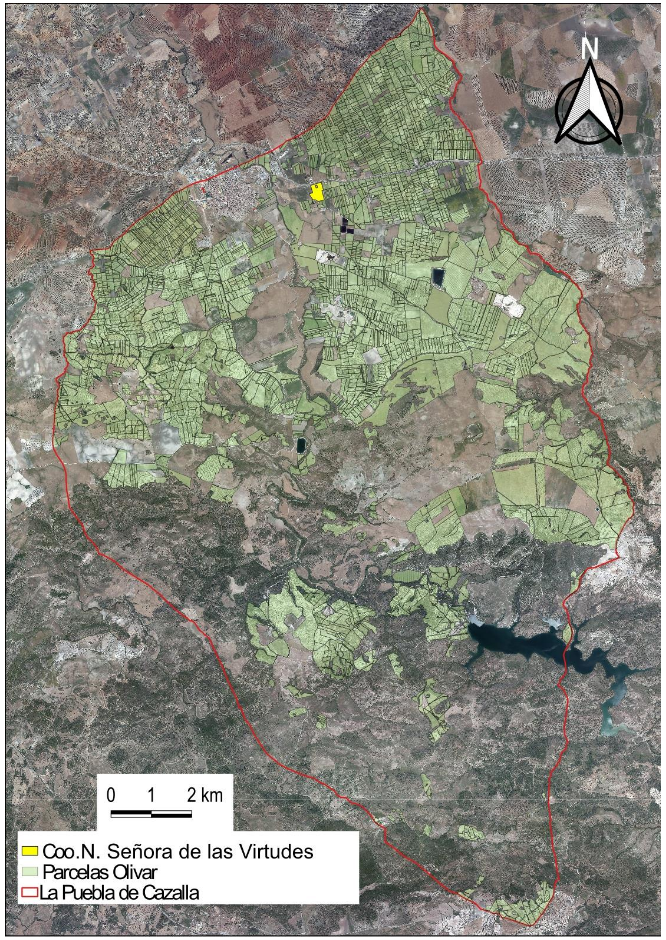


Slope (S)	**Score**
S ≤ 0.08	1
0.08< S ≤ 0.15	0.75
S > 0.15	0.5

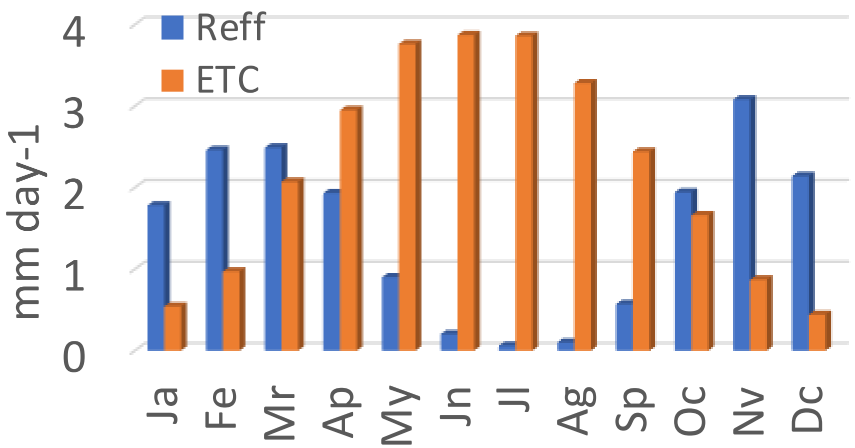
Priority index

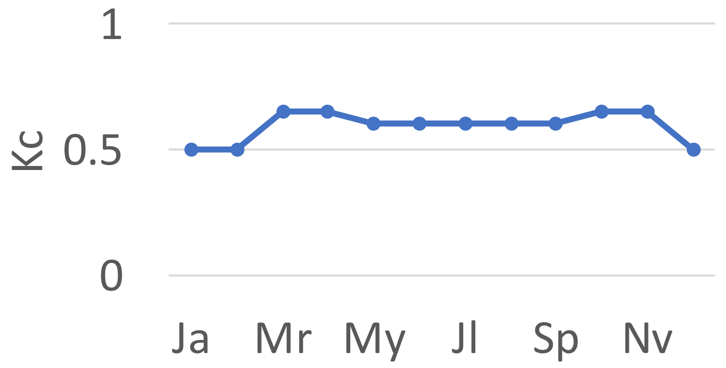
$$\boldsymbol{I} = 0.5D + 0.1T + 0.3W + 0.1S$$





Irrigation requirements





$$P_{eff} = P_t\left(125 - \frac{0{,}2 * P_t}{125}\right)$$

$$\mathrm{ETc} = \mathrm{ETo} * \mathrm{kc} * \mathrm{kr}$$

$K_r = \frac{S_c}{100}$, where S_c stands for the shaded area

$$LF = \frac{EC_{irr}}{2 \cdot EC_e} \qquad Irr = \frac{ET_c}{1 - LF}$$

a) EC_e < 4 dS/m (Barranco y col. 2017).

b) EC_e < 6 dS/m (Weissbein y col. 2008).

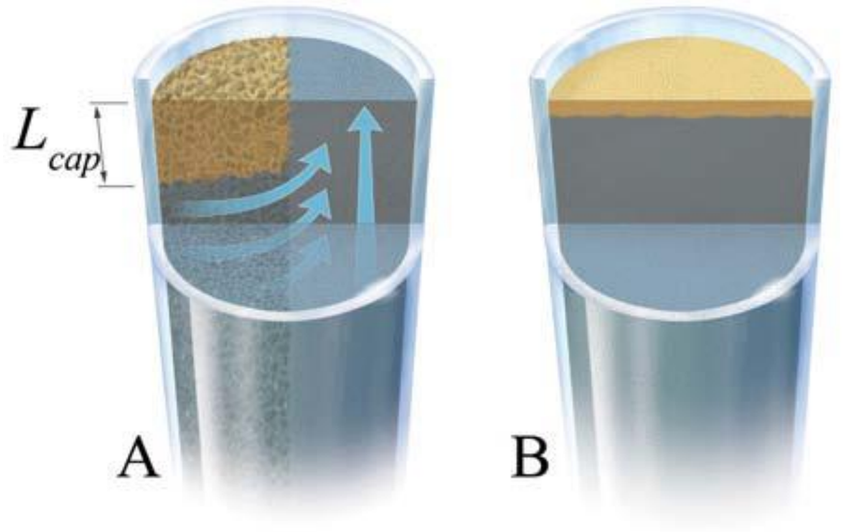
Scenario	Aportación bruta inicial (m3/ha año)	Aportación bruta tras LF (m3/ha año)
A (4 dS/m)	5.576	8.921,6
B (6 dS/m)	5.576	6.691,2

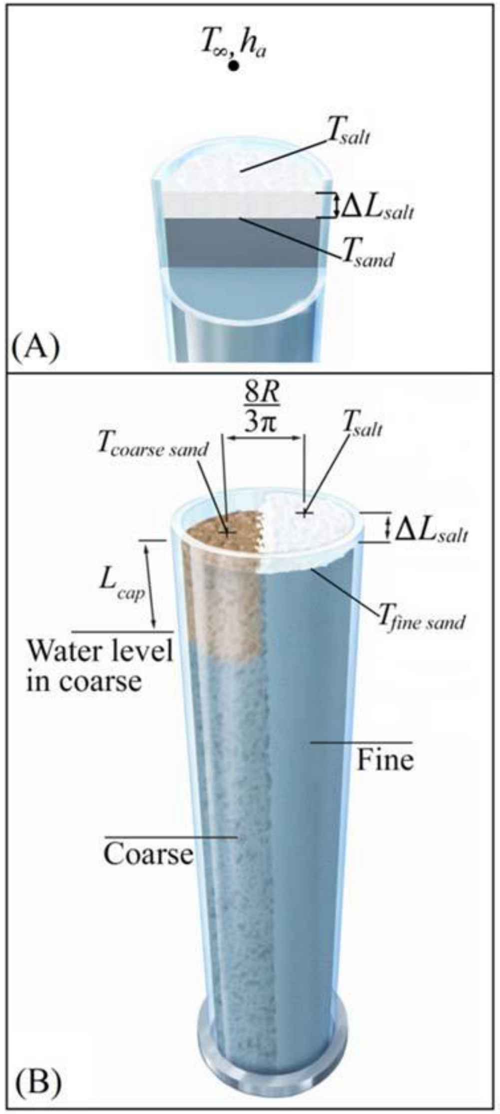
$$EC_{irr} = 3\ dS\ m^{-1}$$

https://www.universidadderiego.com/

5.1. Exploratory modelling of Irrigation management strategies reducing salt accumulation in the root zone of olive tres (How)

Evaporation from heterogeneous media





Water Resources Research

Regular Article | Free Access

Infrared thermography of evaporative fluxes and dynamics of salt deposition on heterogeneous porous surfaces

Uri Nachshon, Ebrahim Shahraeeni, Dani Or, Maria Dragila, Noam Weisbrod

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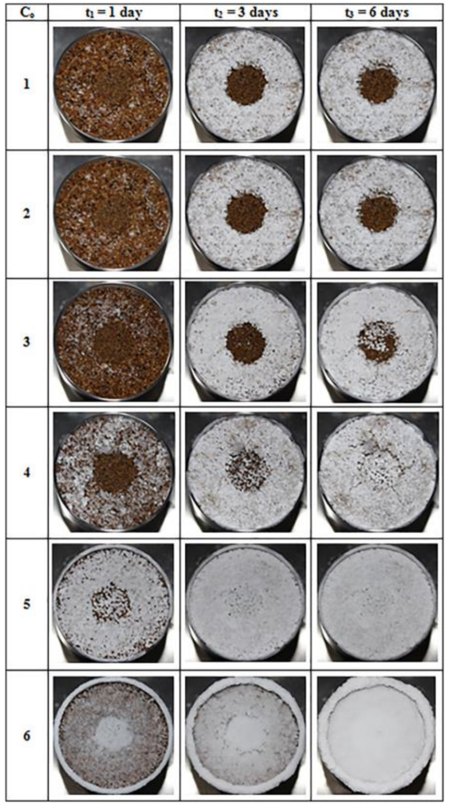
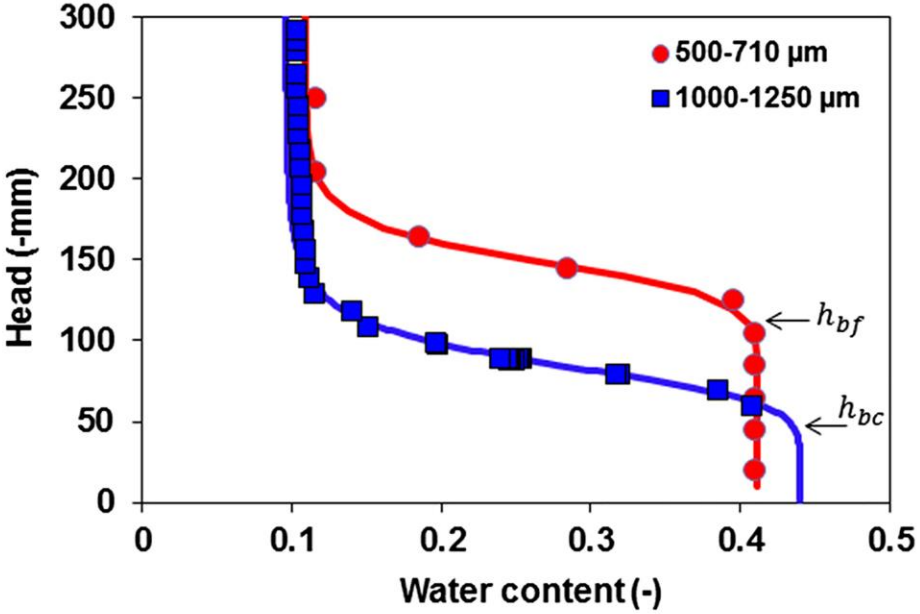
Salt deposition in heterogeneous media

Evolution of precipitation patterns at the surface of heterogeneous porous media (diameter 70 mm) at different concentrations, C_o (mol/L) and time from the onset of the experiment. Note that the inner and out parts of the heterogeneous porous media comprise fine and coarse-textured sand regions, respectively.





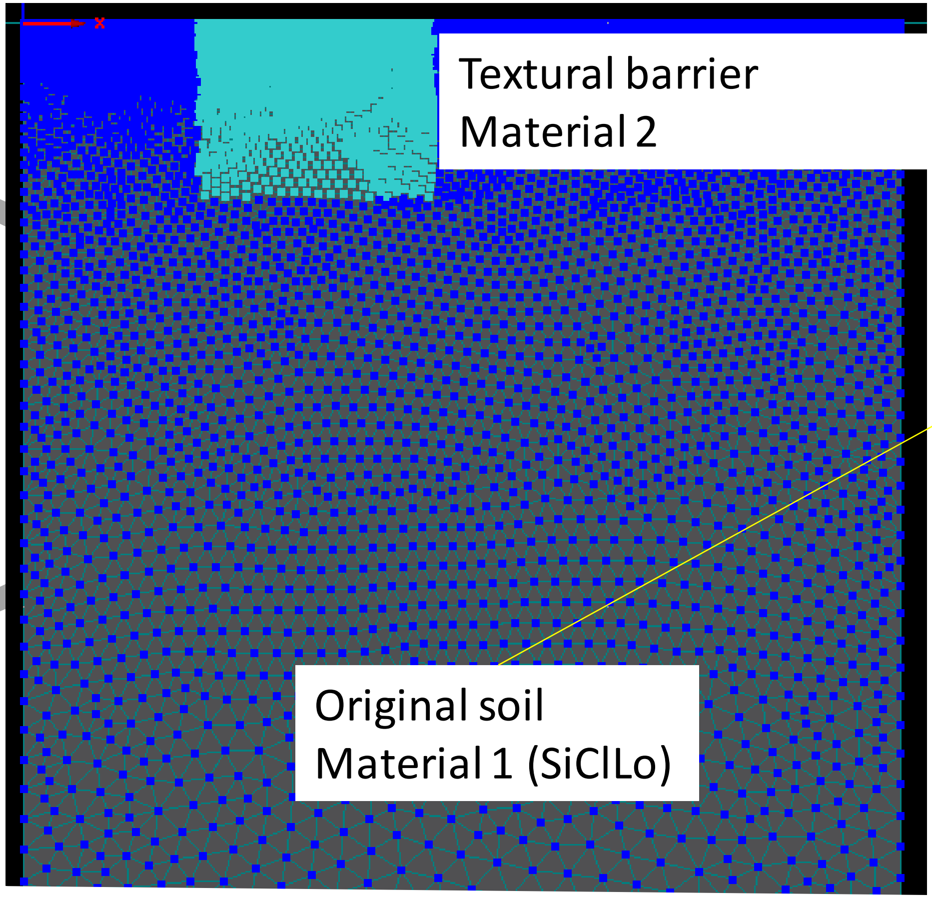
$$\theta = \theta_r + \frac{\theta_s - \theta_r}{\left[1 + (\alpha \cdot |h|)^n\right]^{1-\frac{1}{n}}}$$

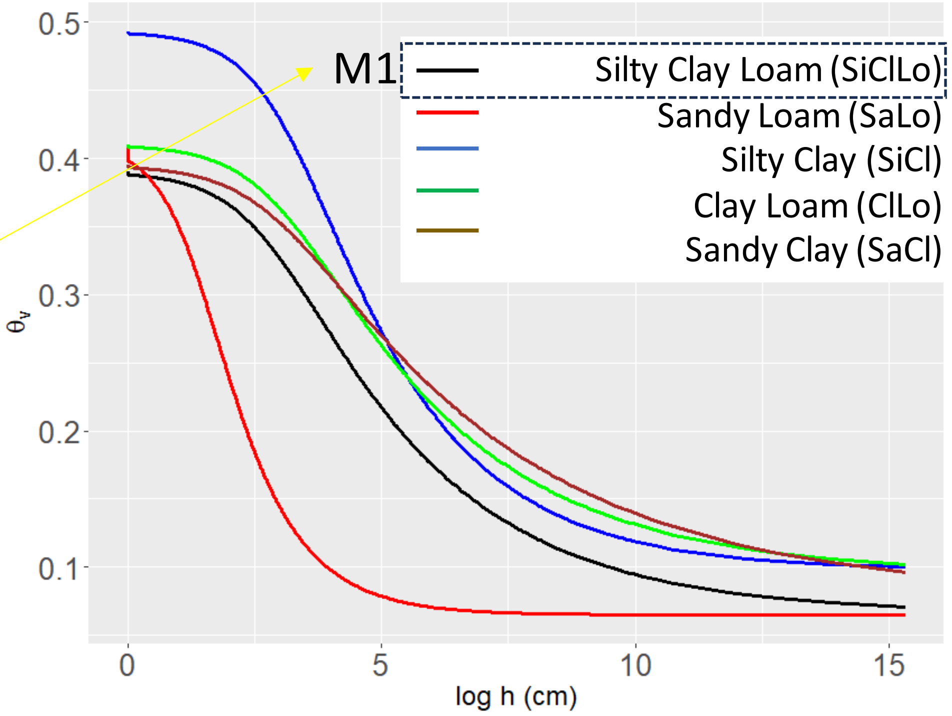
$$h_b = \frac{1}{\alpha}\left[\left(\frac{n}{n-1}\right)^{2-\frac{1}{n}} - \frac{1}{n}\left(1+\frac{n}{n-1}\right)^{2-\frac{1}{n}}\right]$$

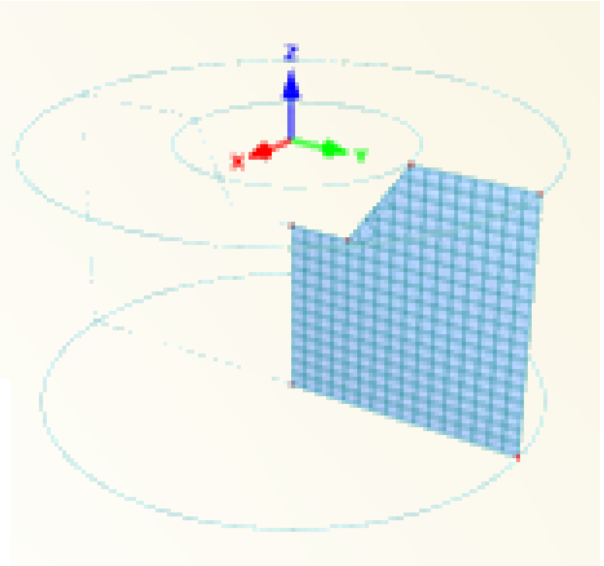
Simulations

- Quasi 3D modelling water and solutes Flow and transport. Axysimmetrical domain
- Stationary approximation
- Drip irrigation - > CE 5 mSm-1. wet radius 12 cm. Emmiters located at 45 cm. 50 mm day^{-1}
- 1 yr Simulation

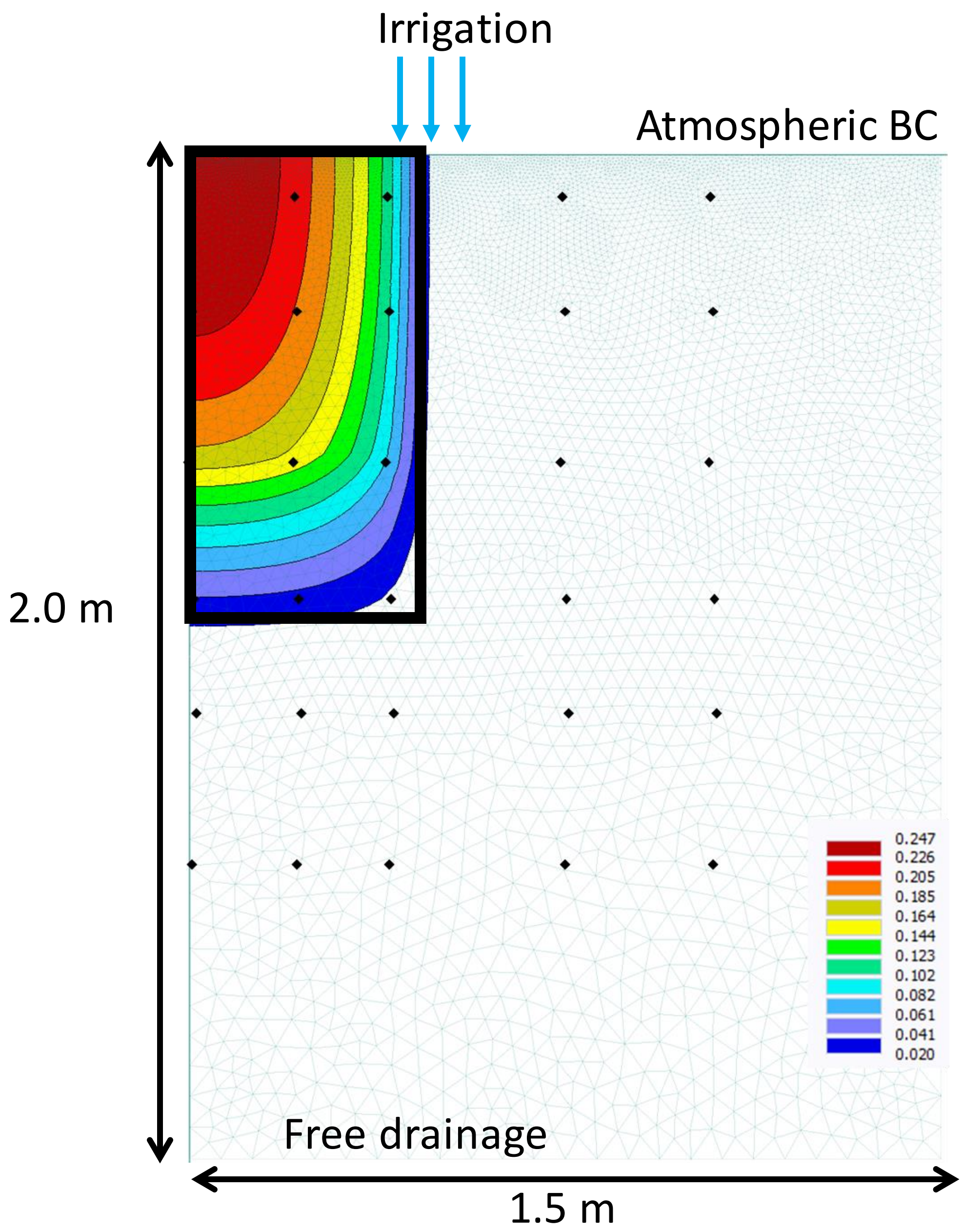
Simulation Domain properties







Simulation Domain properties



Initial condition

θ 0.25 $m^3\ m^{-3}$

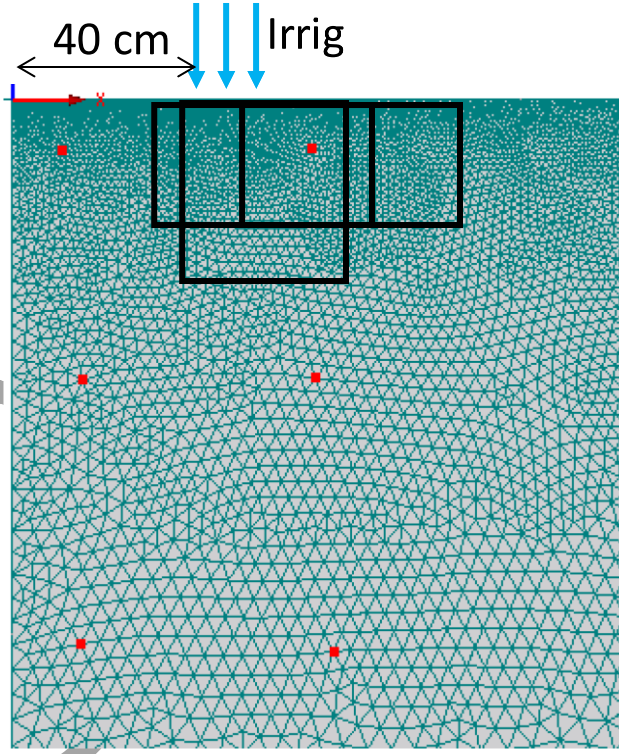
EC 0.3 $dS\ m^{-1}$

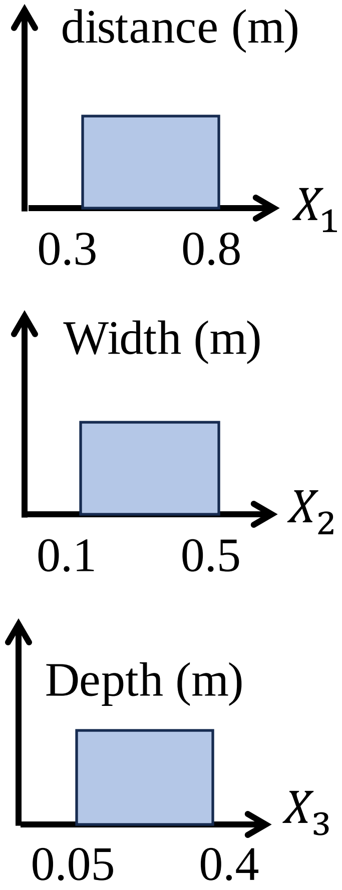
Transpiration reduction

θ availability (Feddes Model)

Saline stress

Sensitivity Analysis methodology





Morris method – Global sensitivty analysis

Latin hypercube sampling

400 simulations (100 levels, 3 predictors, X_i)

Objective function

$$y = \frac{EC^{Barr}}{EC^{raw}}$$

Elementary indices

$$EE_i^j = \frac{y(X_1^j,\dots,X_i^j + \Delta,\dots,X_M^j) - y(X_1^j,\dots,X_i^j,\dots,X_M^j)}{\Delta}$$

Average of absolute value EE_i^j - > Total effect

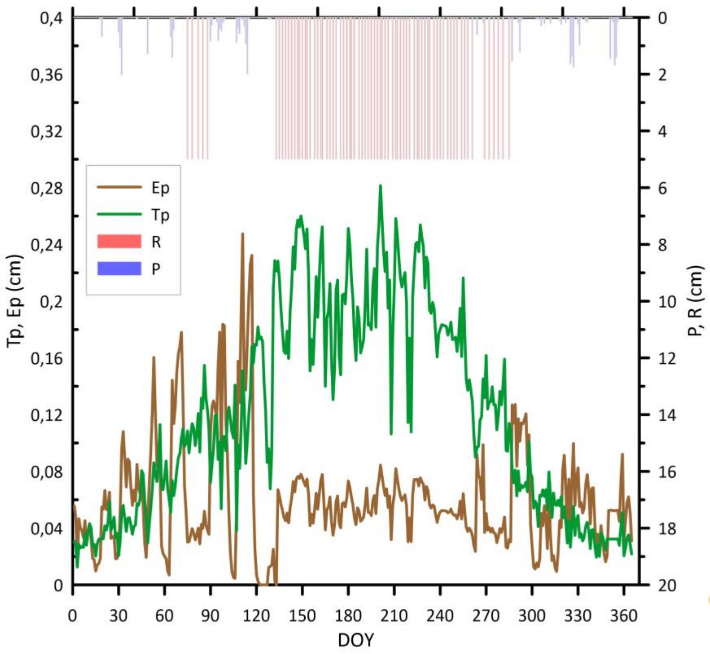
$$S_i = \frac{\mu_i^*}{max\ \mu_k^*}$$

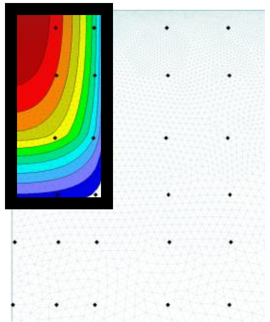
Standard deviation -> predictors interactions

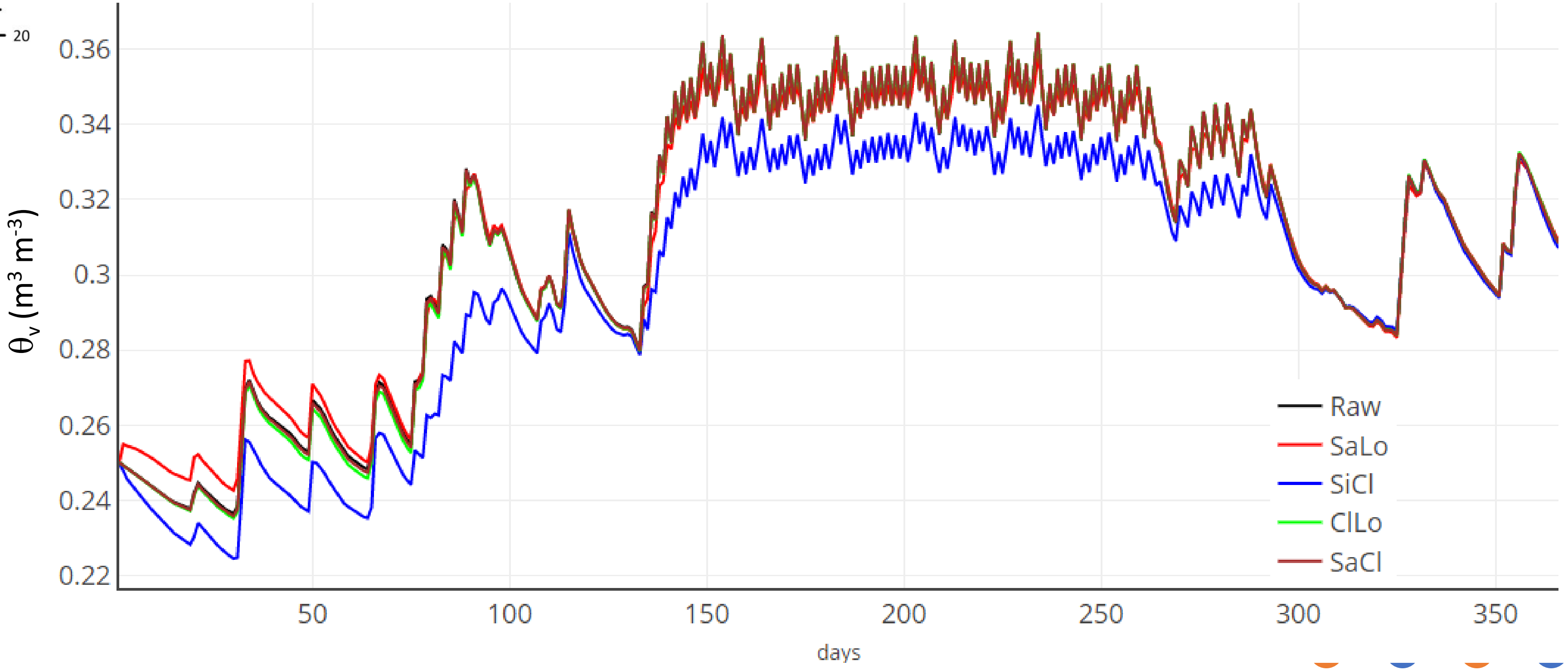
The Sensitivity Analysis For Everyone (SAFE) toolbox

https://safetoolbox.github.io/

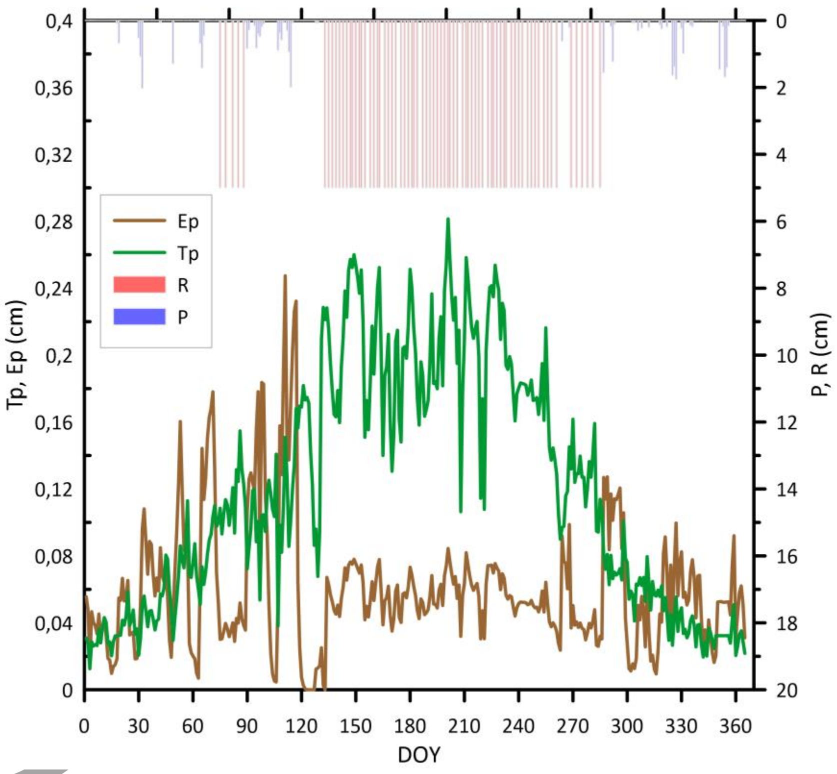
Temporal evolution of θ_v



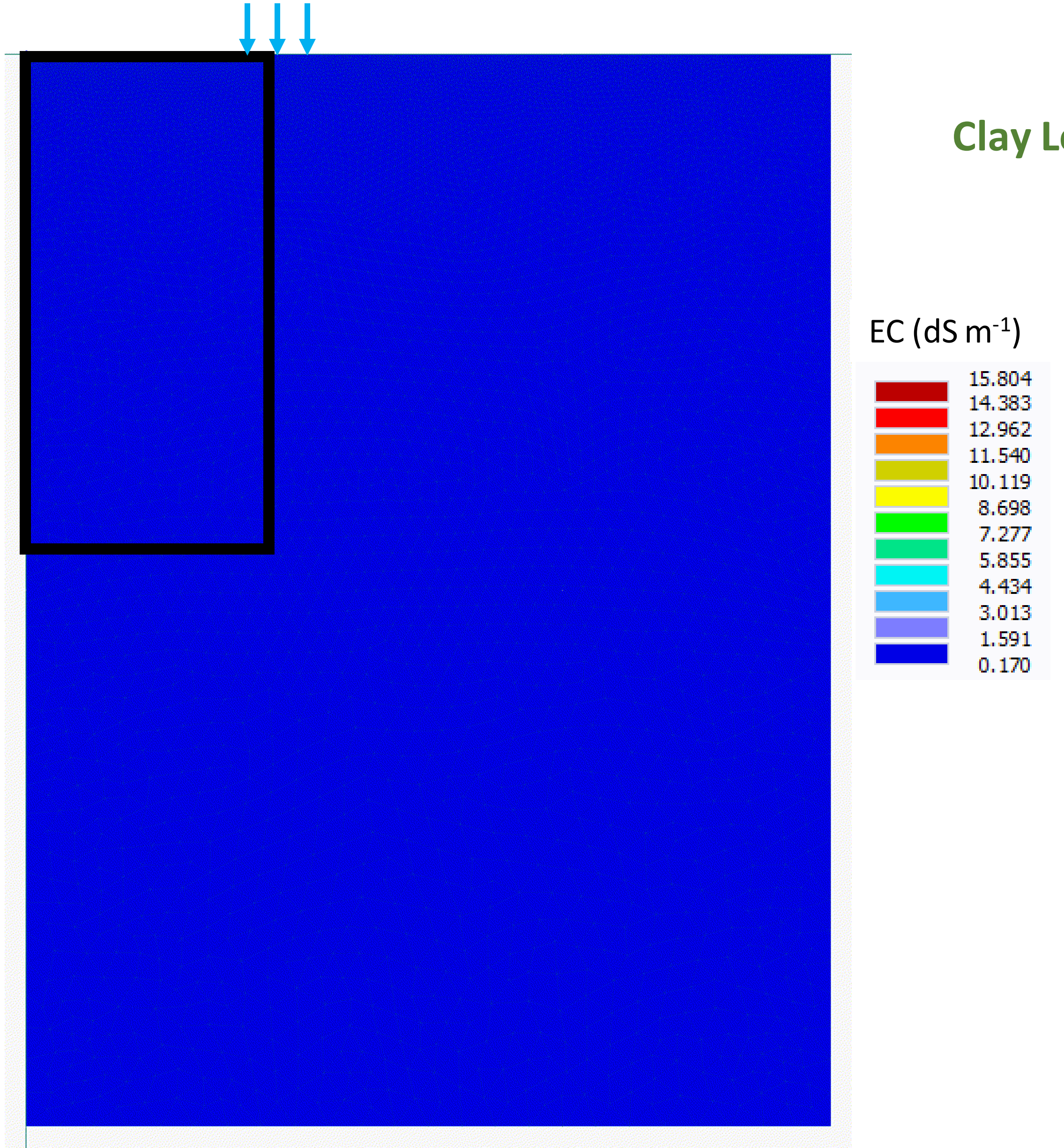




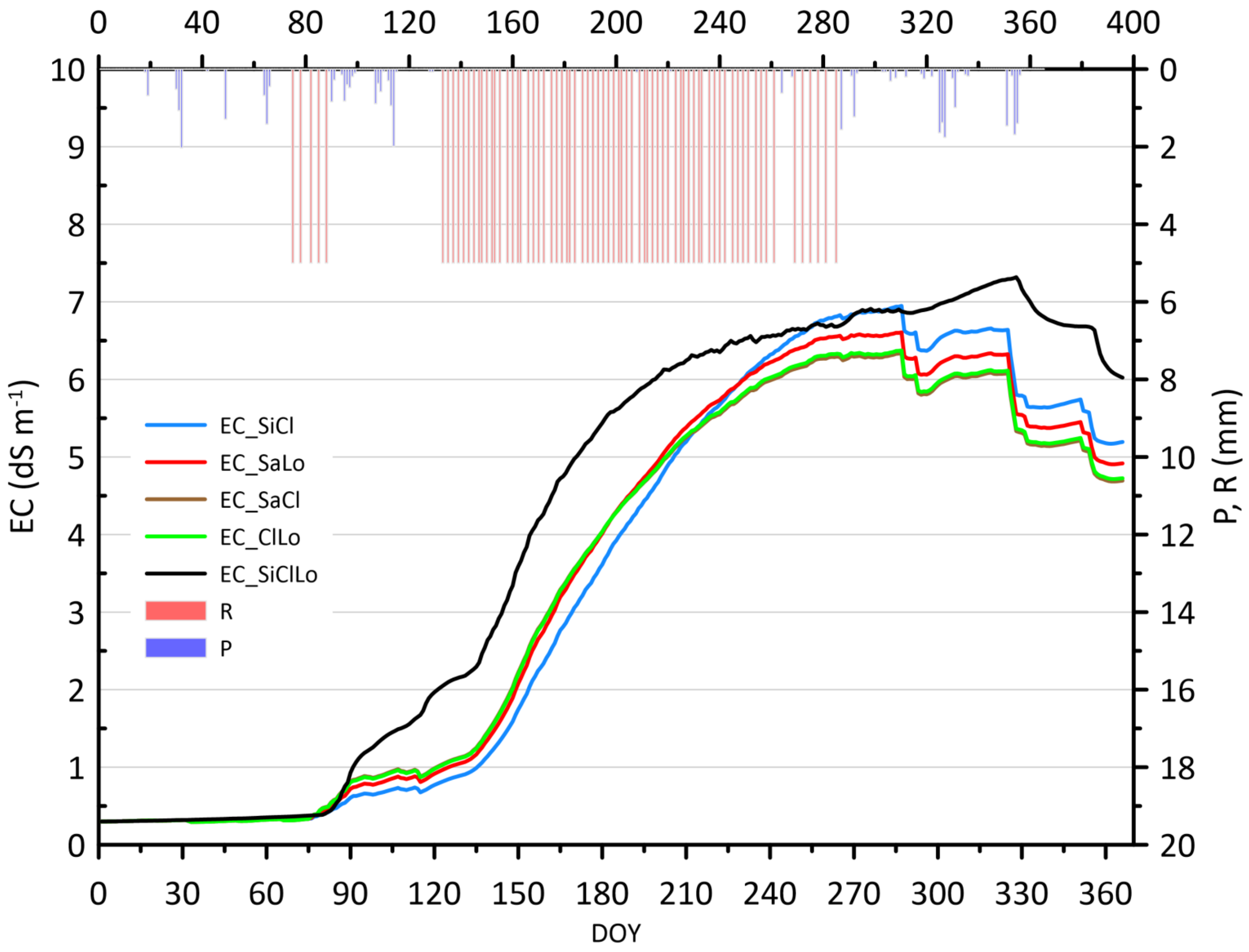
EC patterns

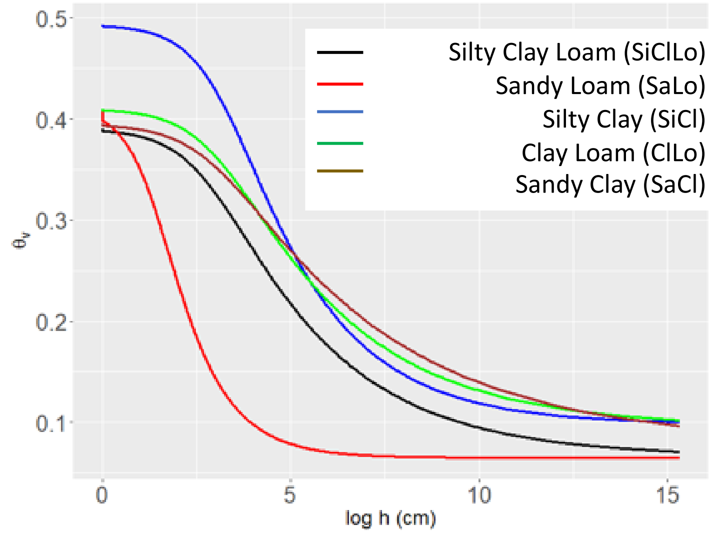


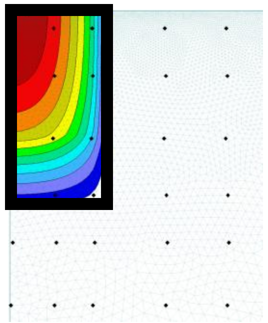
Clay Loam

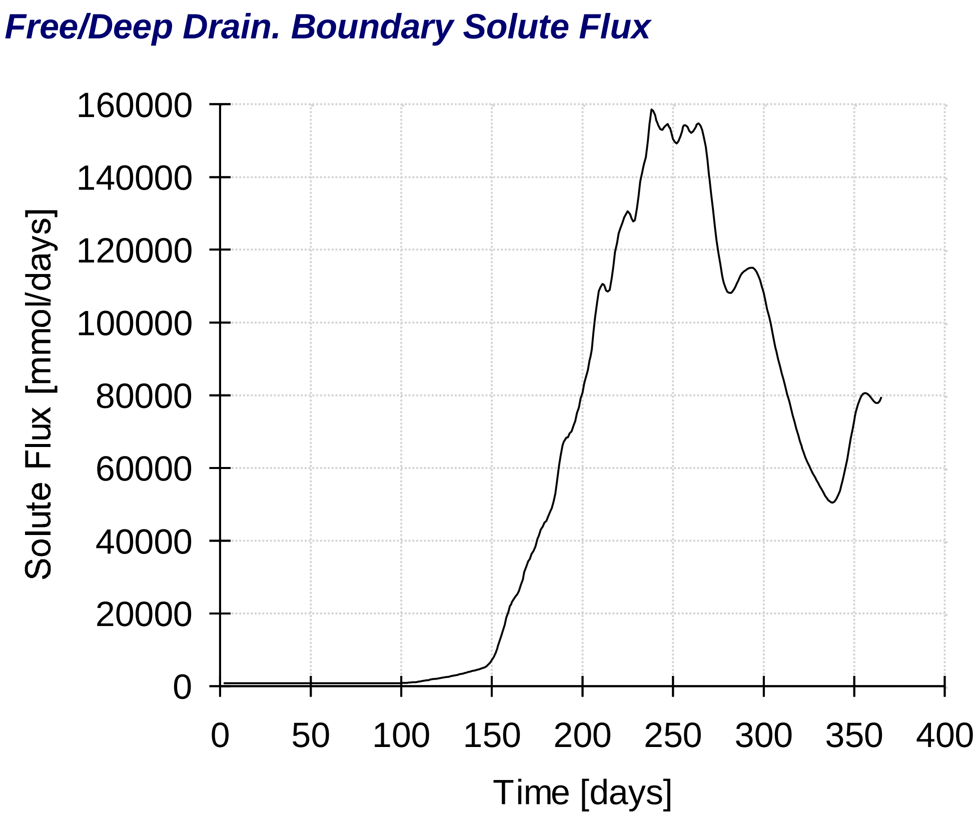


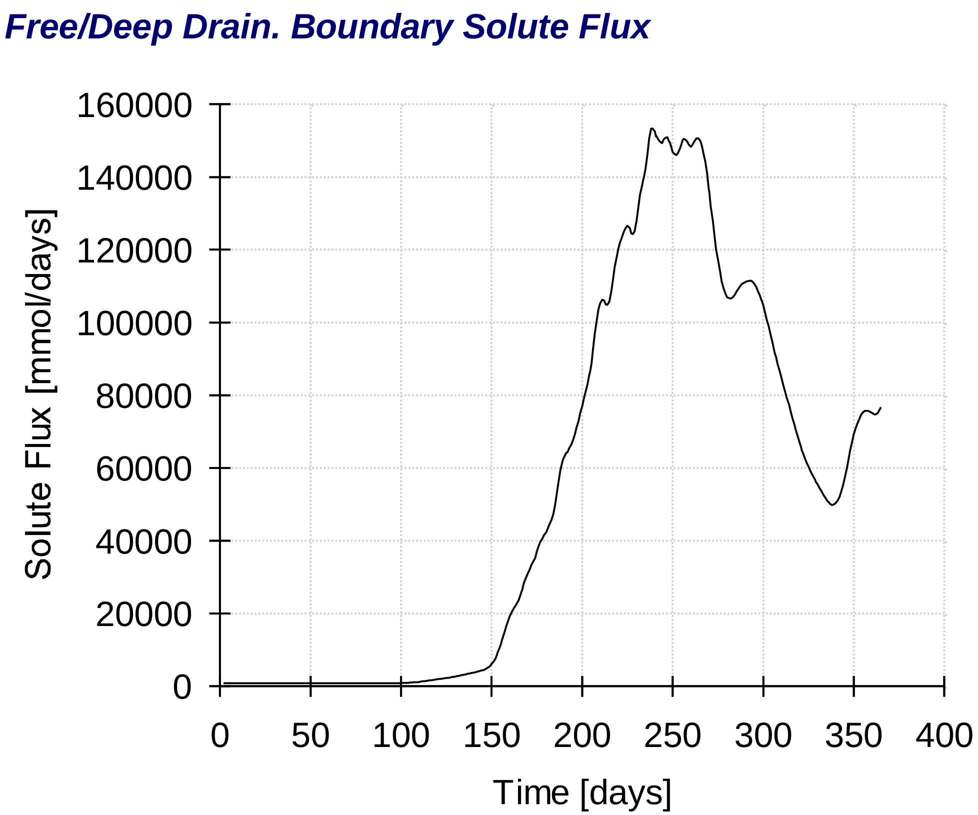
Temporal evolution of EC








Free/Deep Drain. Boundary Solute Flux
160000
140000
120000
100000
80000
60000
40000
20000
0
Solute Flux [mmol/days]
0
50
100
150
200
250
300
350
400
Time [days]


Free/Deep Drain. Boundary Solute Flux
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0
Solute Flux [mmol/days]
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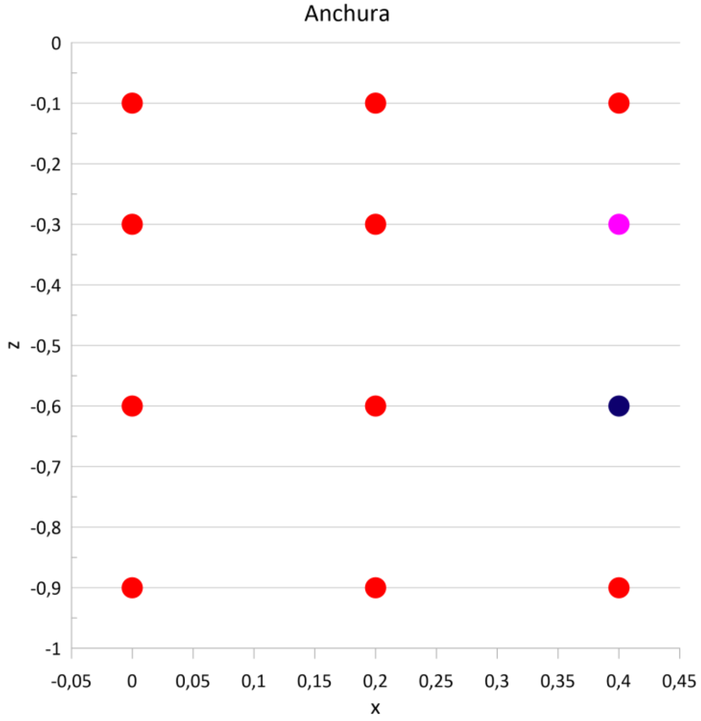
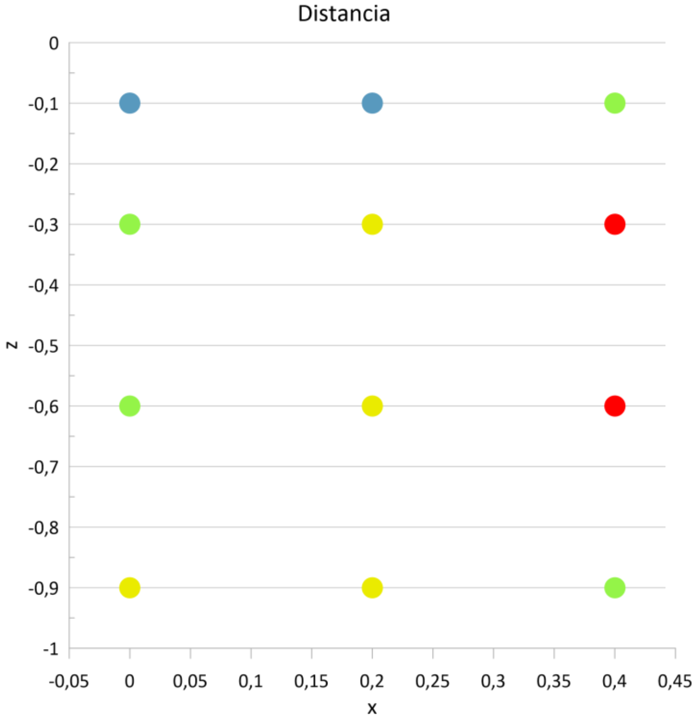
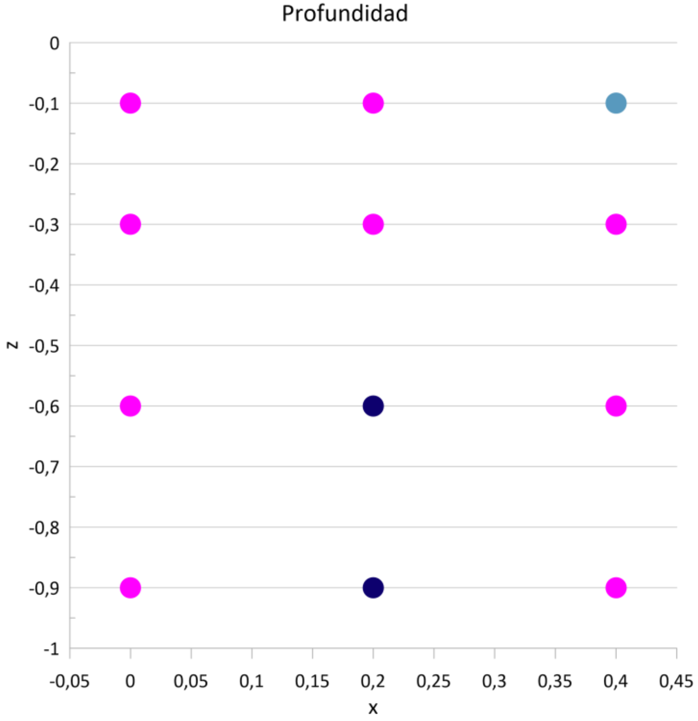
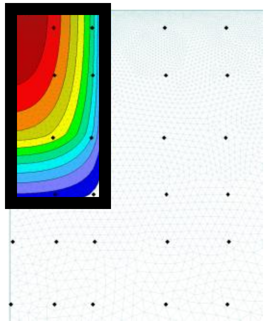
250
300
350
400
Time [days]

Sensitivity analysis. Total effects









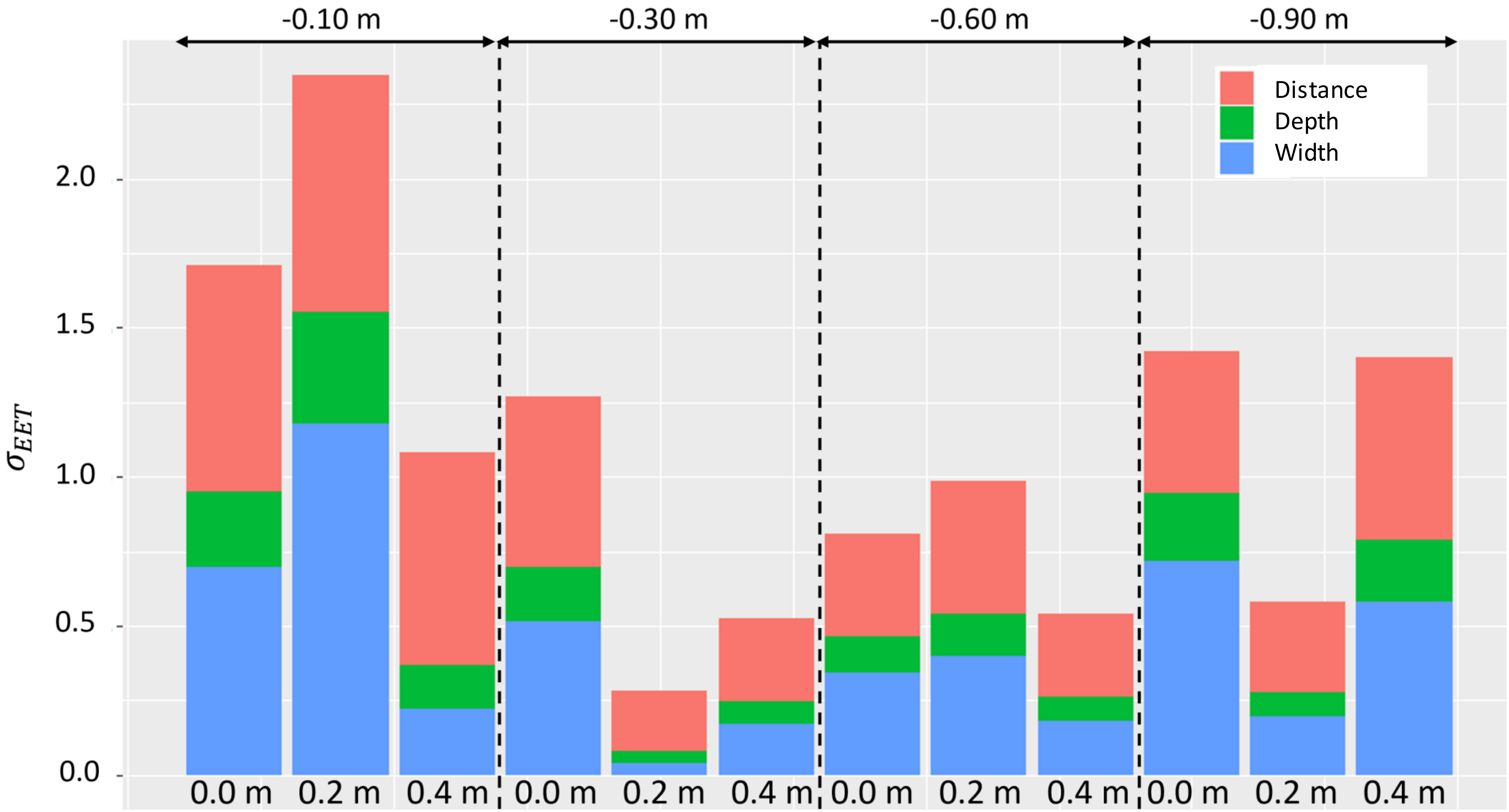
Clay Loam

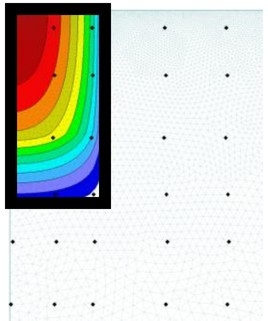
$$S_i = \frac{\mu_i^*}{max\ \mu_k^*}$$

- 0 to <0.5
- 0.5 to <0.6
- 0.6 to <0.7
- 0.7 to <0.8
- 0.8 to <0.9
- 0.9 to <1.0

Sensitivity analysis. Interactions

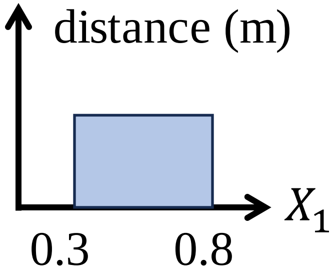
Clay Loam

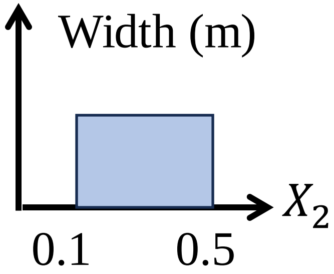


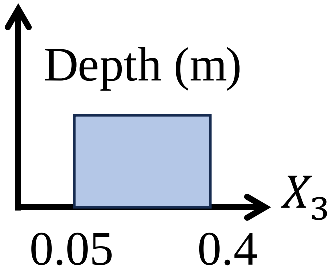


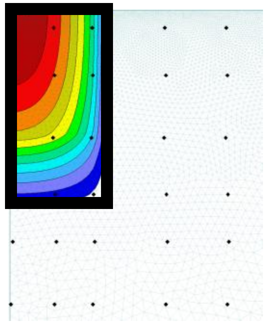
Barrier Dimensions

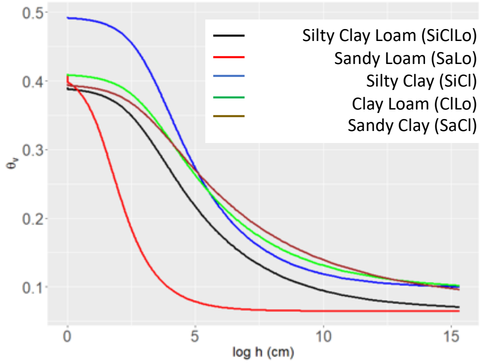
Largest EC_{max} reduction	Distance (cm)	Width (cm)	Depth (cm)	Ratio EC_{max}	Ratio EC_{final}
SiCl	42	48	39	0.95	0.86
SaLo	45	12	33	0.90	0.82
SaCl	31	13	22	0.87	0.78
ClLo	31	13	22	0.87	0.78





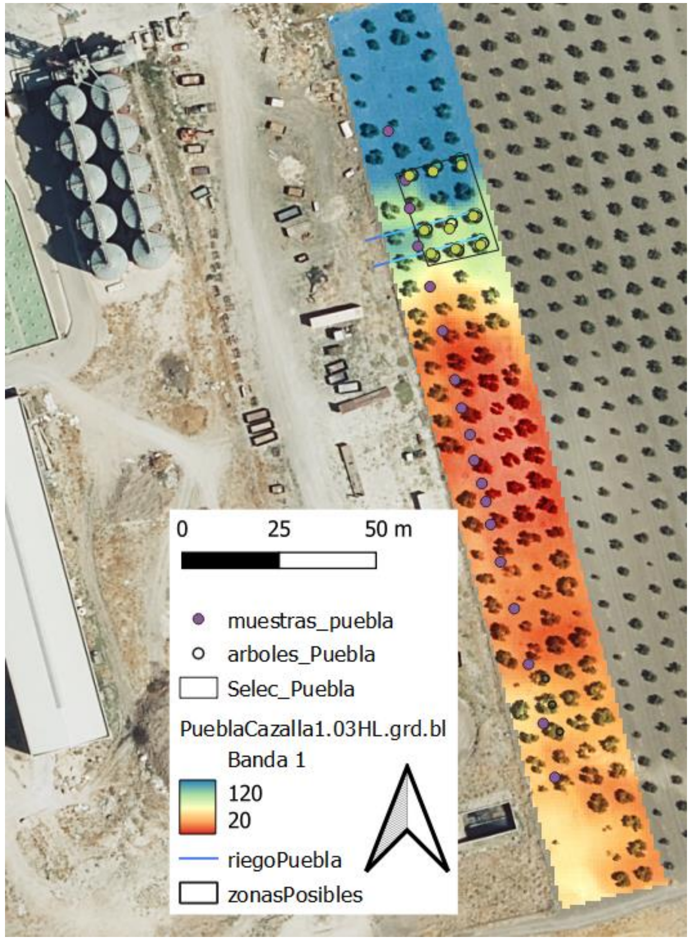






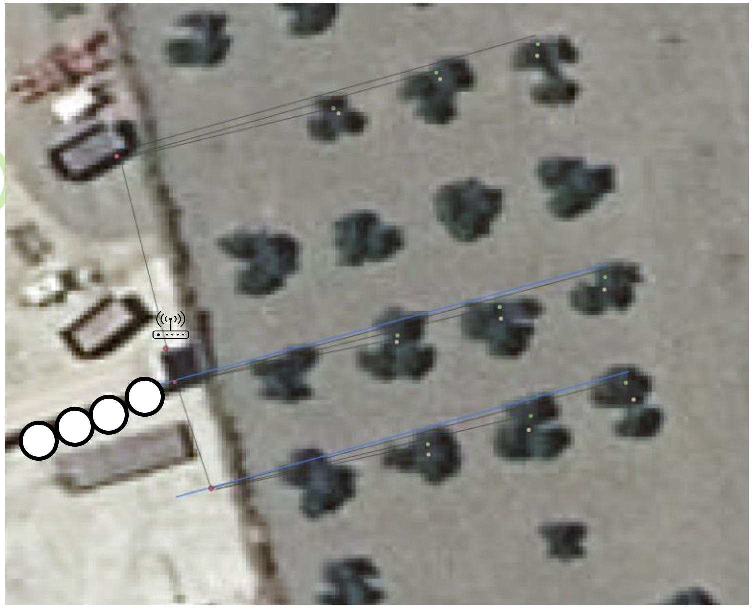
5.2. Field experiment to evaluate Irrigation management strategies reducing salt accumulation in the root zone of olive trees

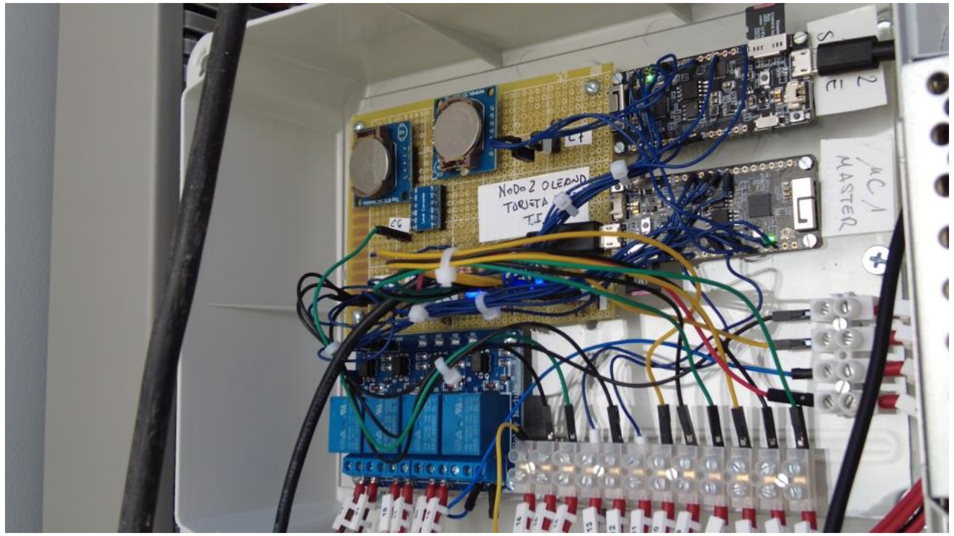
Field characterization

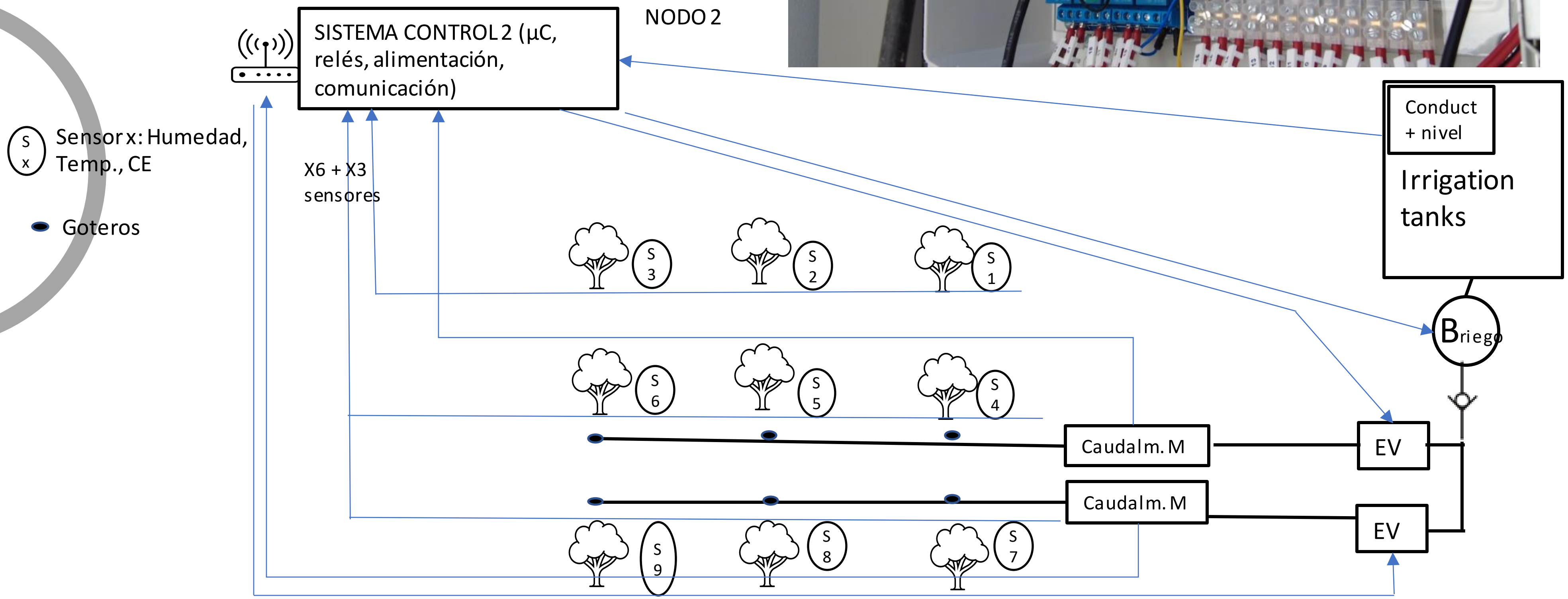


Field experiment

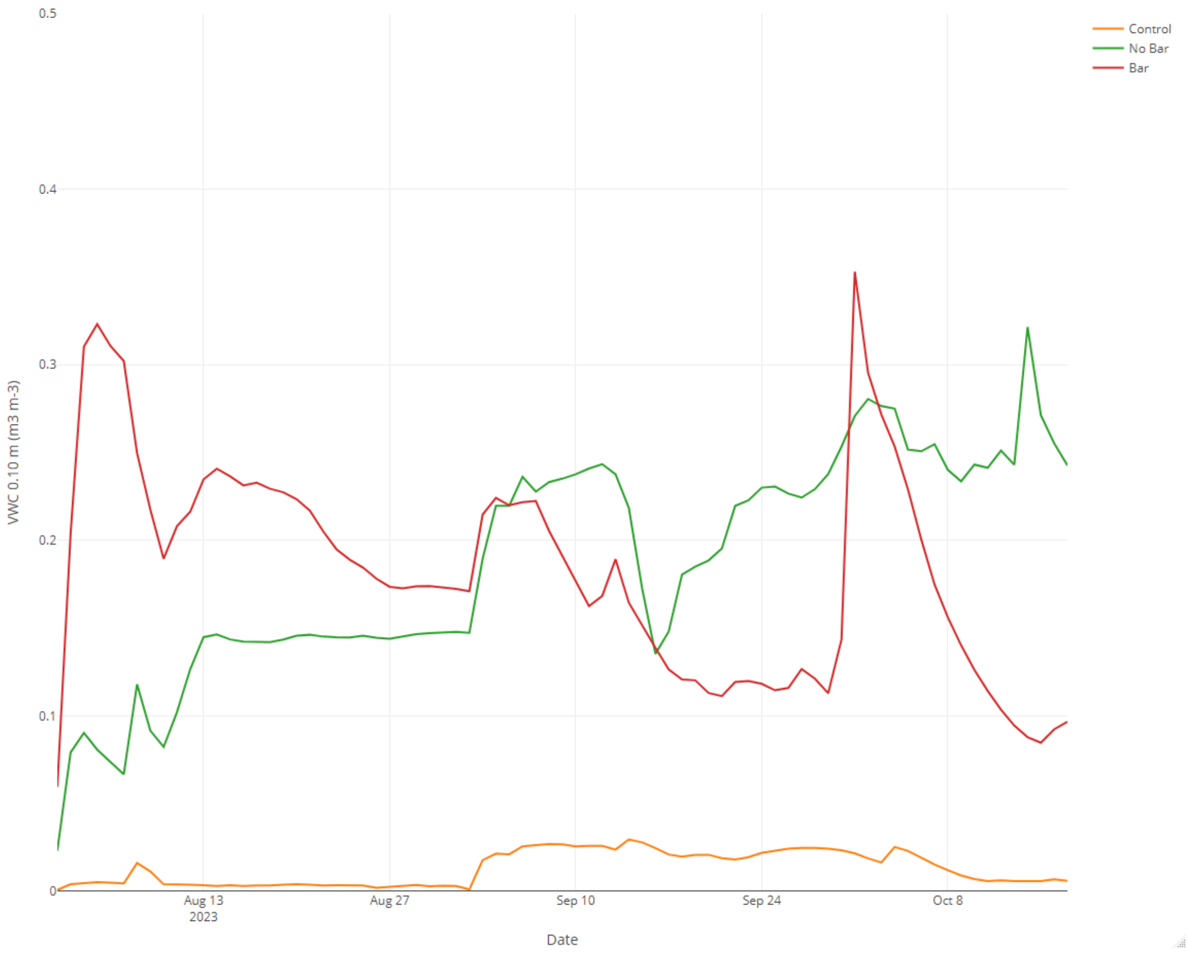
Control system

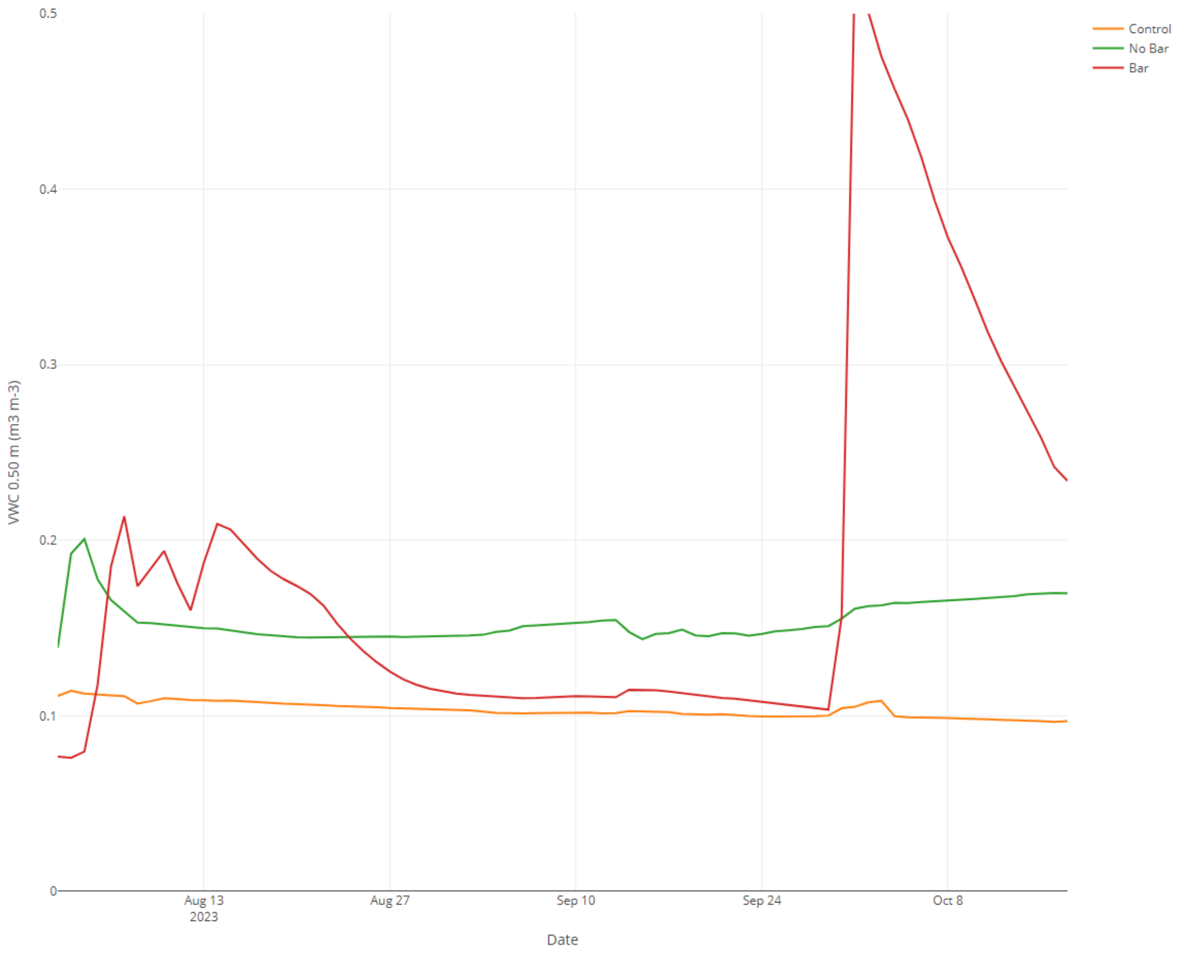




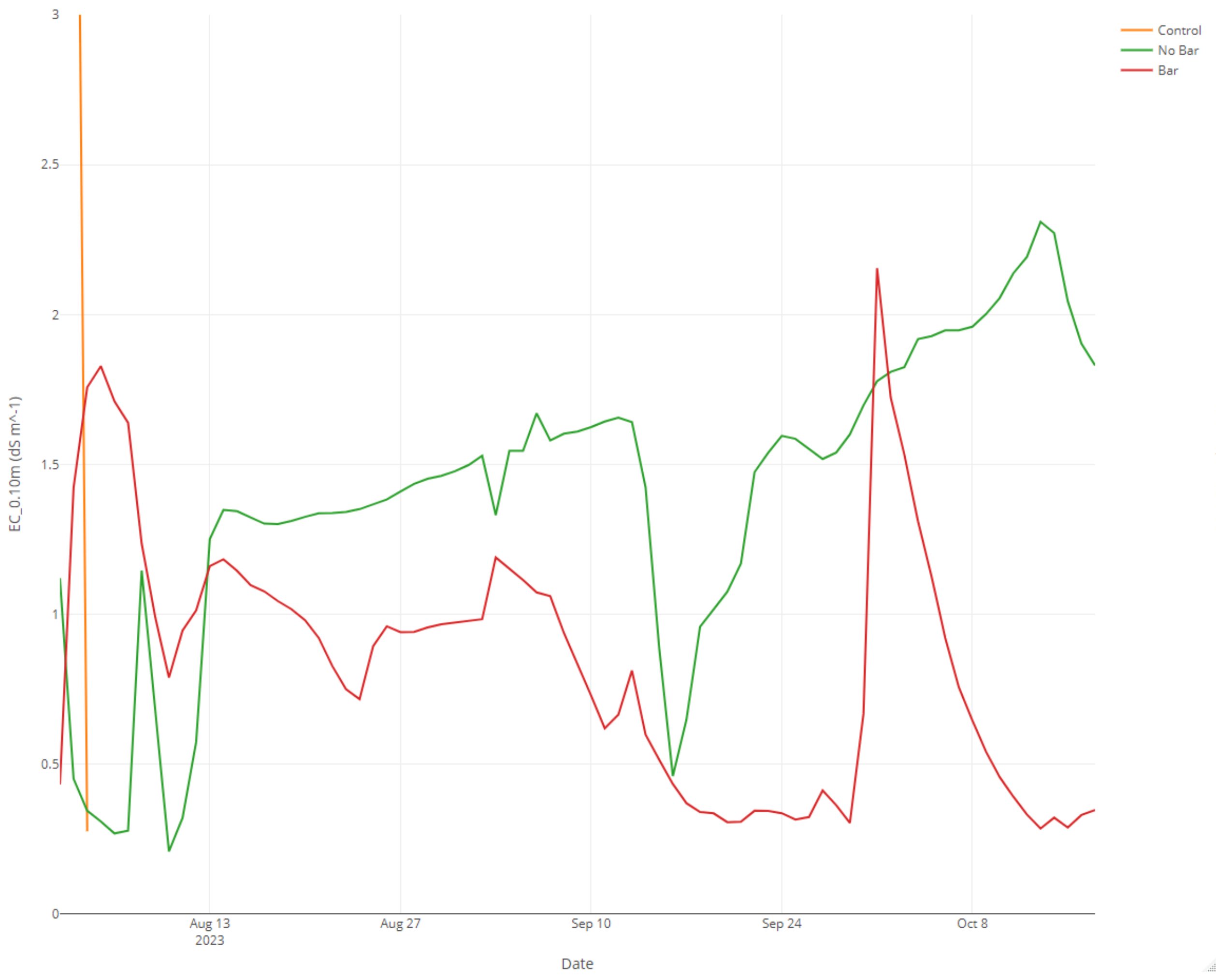


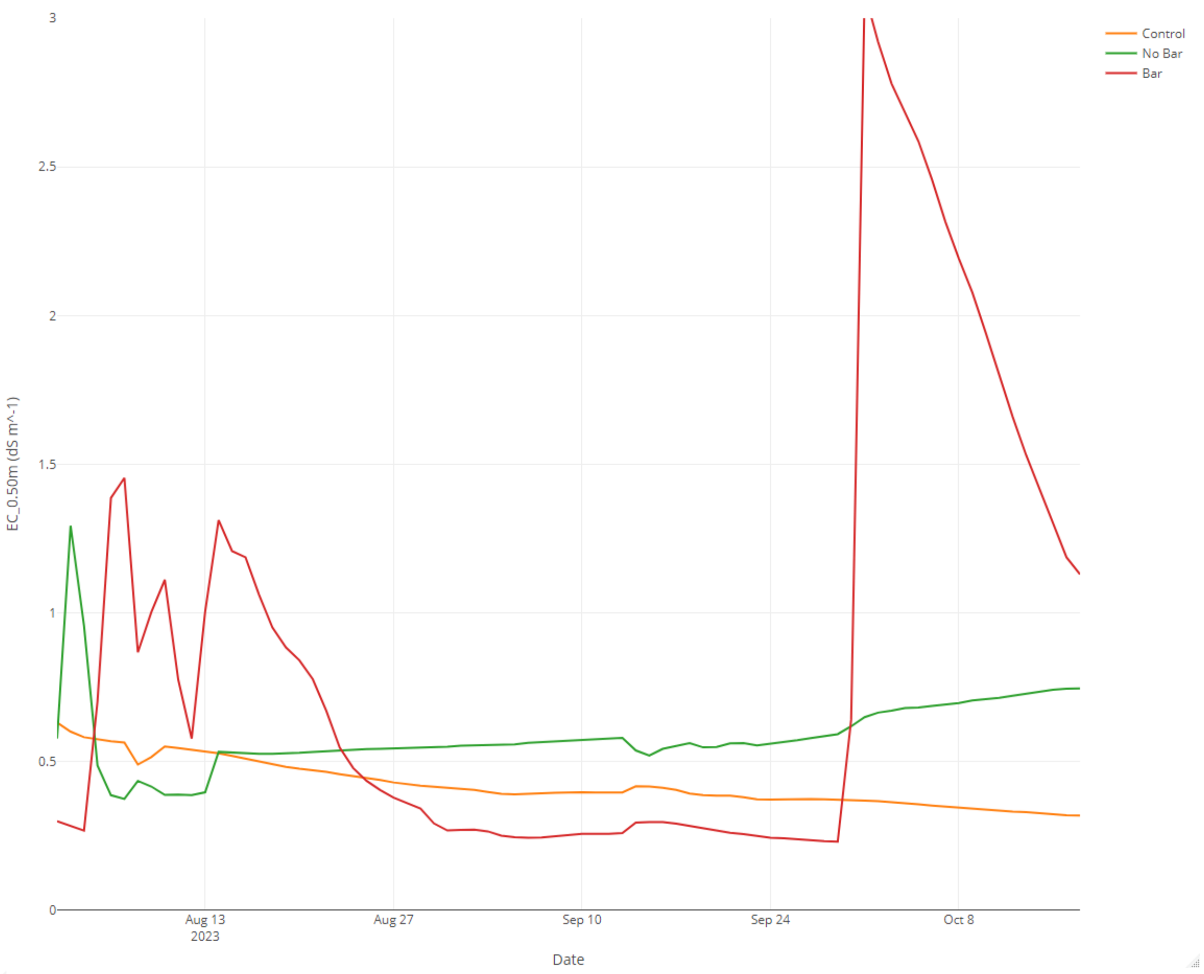
Water content measurements





Soil EC measurements





Fruits comparison

5. Conclusions

5. Conclusiones

- **Large production** of effluents with **highly variable** EC depending on location and time requiring **continuous monitorization** and real-time separation to be used for irrigation
- **GIS based tools** are useful to define the optimum locations for olive pickling industry effluents irrigation.
- **Leaching fraction** approach requires excessively large irrigation amounts
- **SA** of a Water flow and solute transport model provide valuable information to evaluate the potential of alternative irrigation management strategies such as textural barriers
- Textural barriers efficiency mostly dependent on soil texture and distance of installation
- After 1 season of irrigation mild to low salinization of the soil profile.
- Fruits are bigger and in better conditions compared to dryland farming
- Longer term evaluation will provide conclusions about the sustainability of this management

Thank you!!!

Potential of the olive pickling industry greywaters for the sustainable irrigation of olive orchards. Management alternatives to reduce salinization risk

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