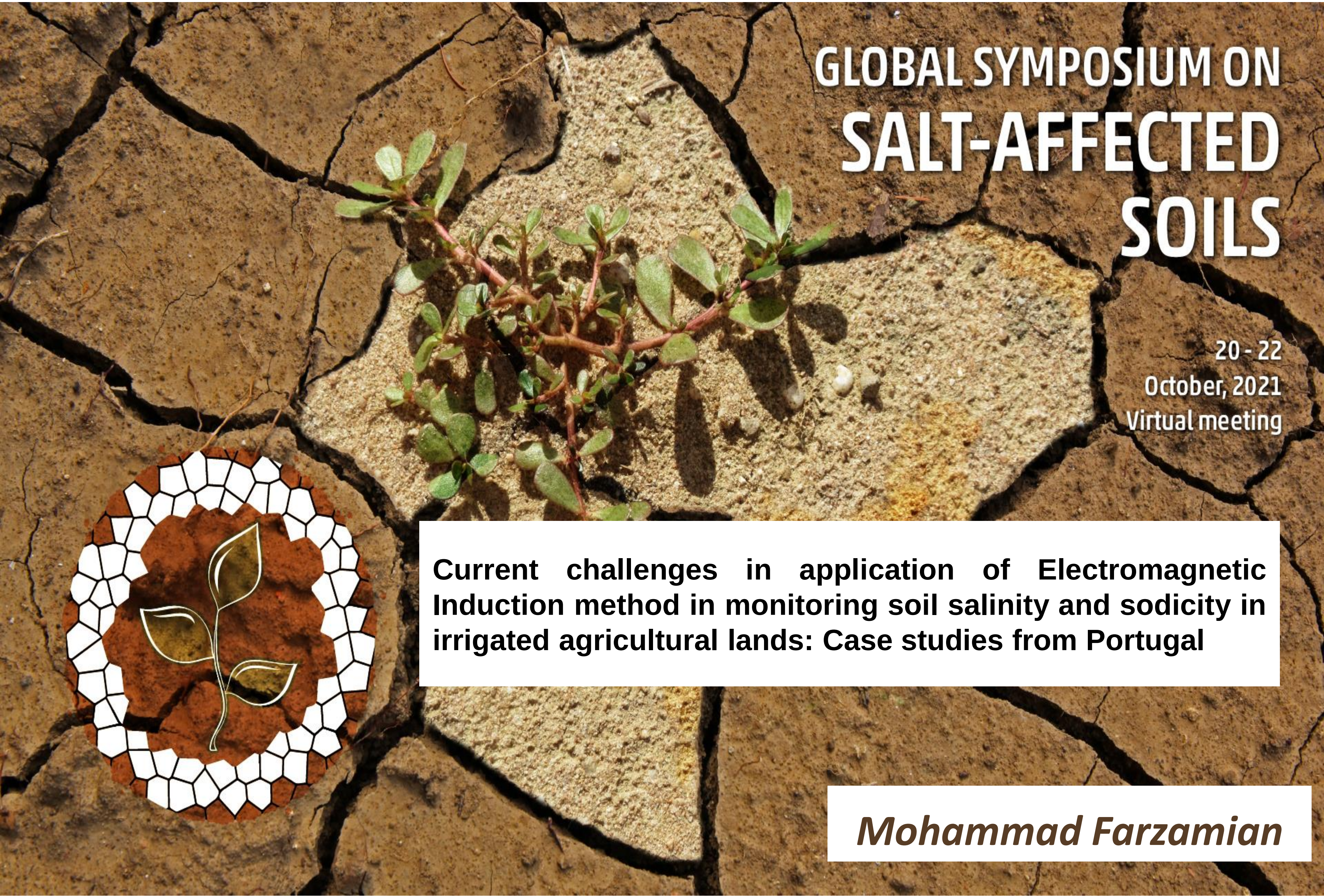


Current challenges in application of Electromagnetic Induction method in monitoring soil salinity and sodicity in irrigated agricultural lands: Case studies from Portugal

Mohammad Farzamian

SALTFREE and SOIL4EVER projects

Goal:
Develop a framework for evaluation of the **salinization risk** in irrigated production systems in **management scale** using **EM technique**.

Research Question

Can we use an **Electromagnetic sensor**

\+

inversion process

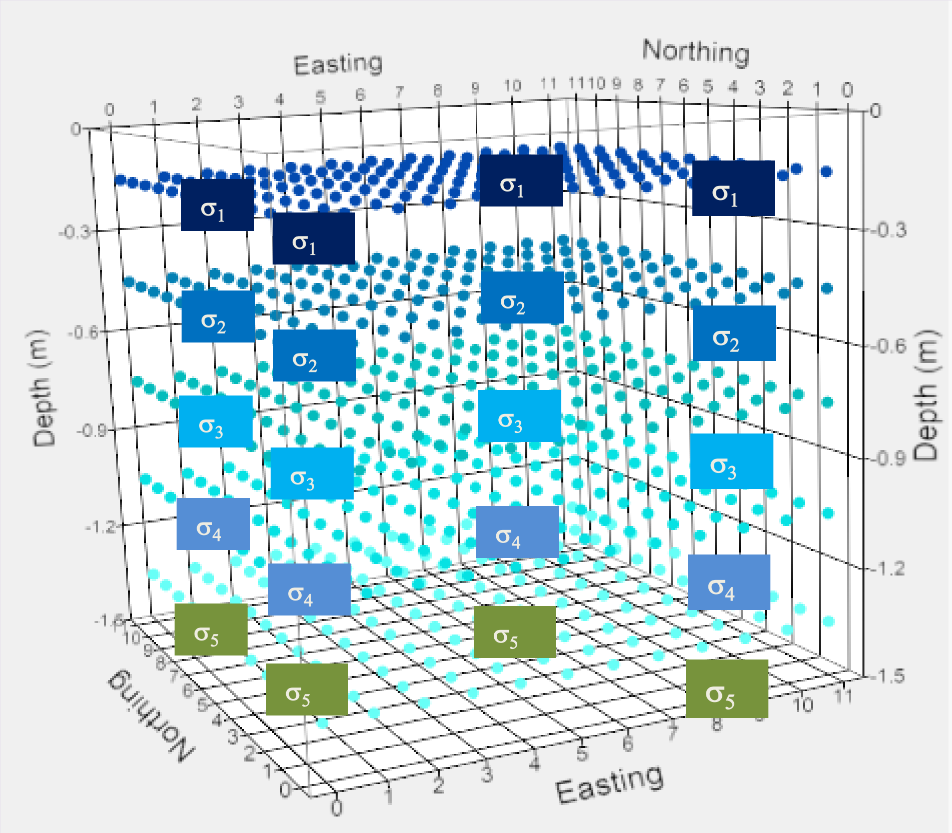
To generate temporal 2D and 3D salinity maps

SALTFREE and SOIL4EVER projects

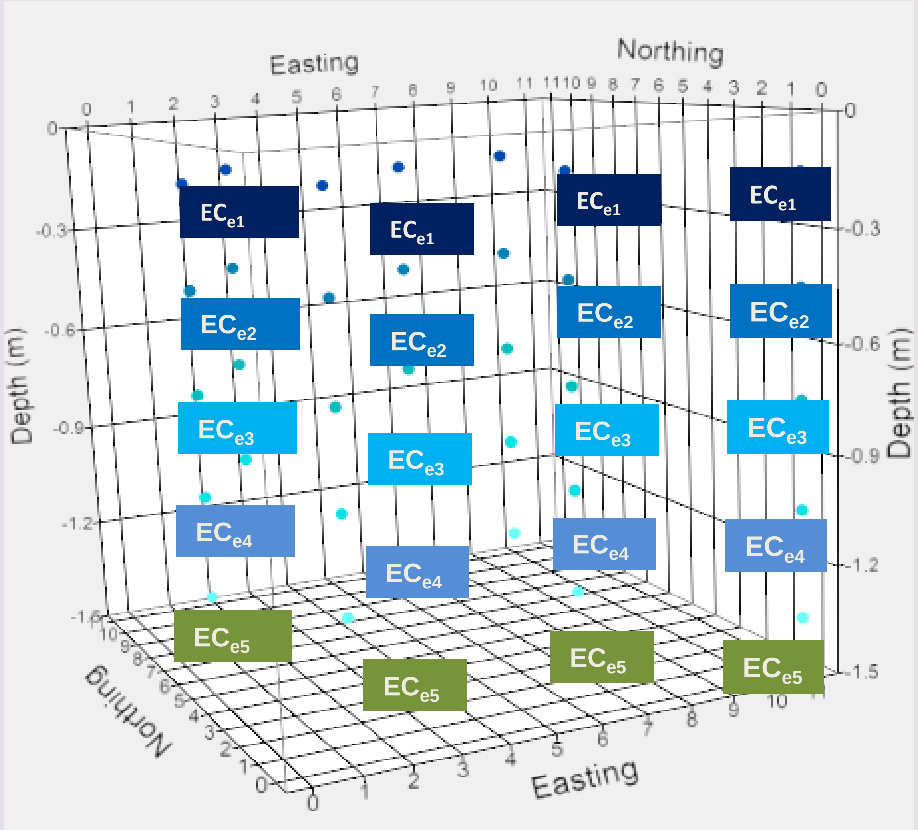
Goal:

Develop a framework for evaluation of the **salinization risk** in irrigated production systems in **management scale** using **EM technique**.

Predicted σ from EM data modelling



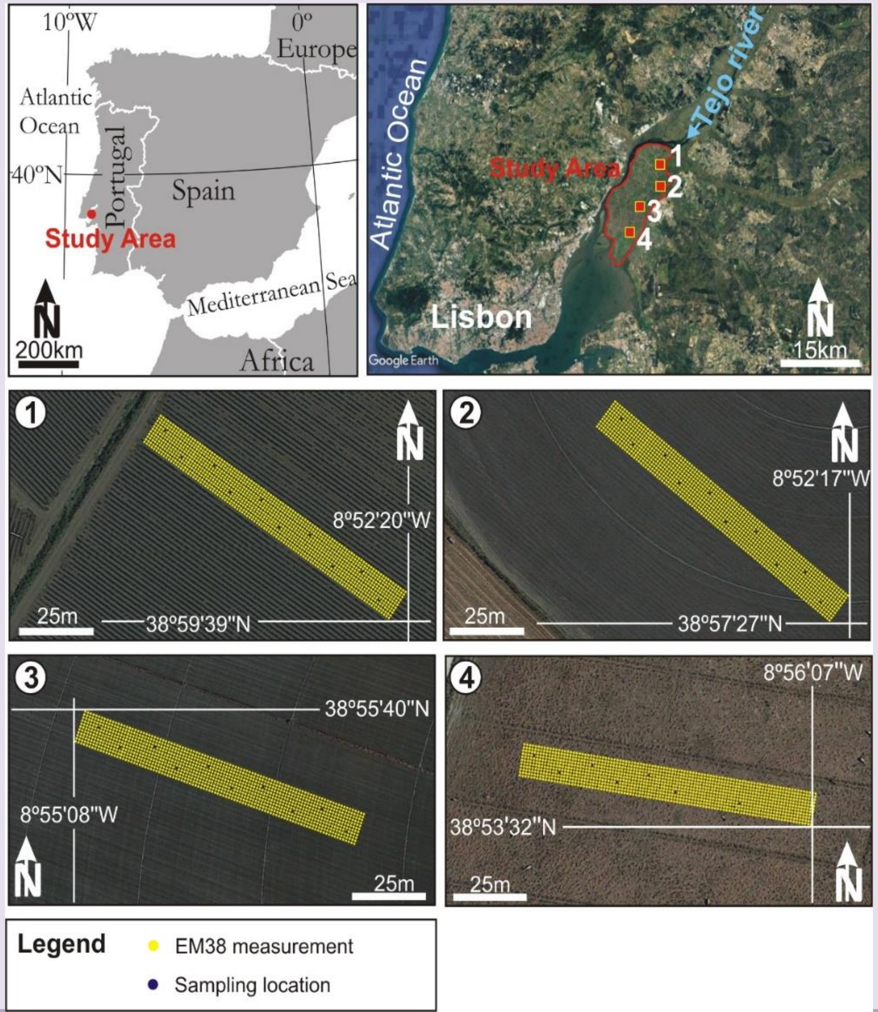
Soil sampling and laboratory analysis



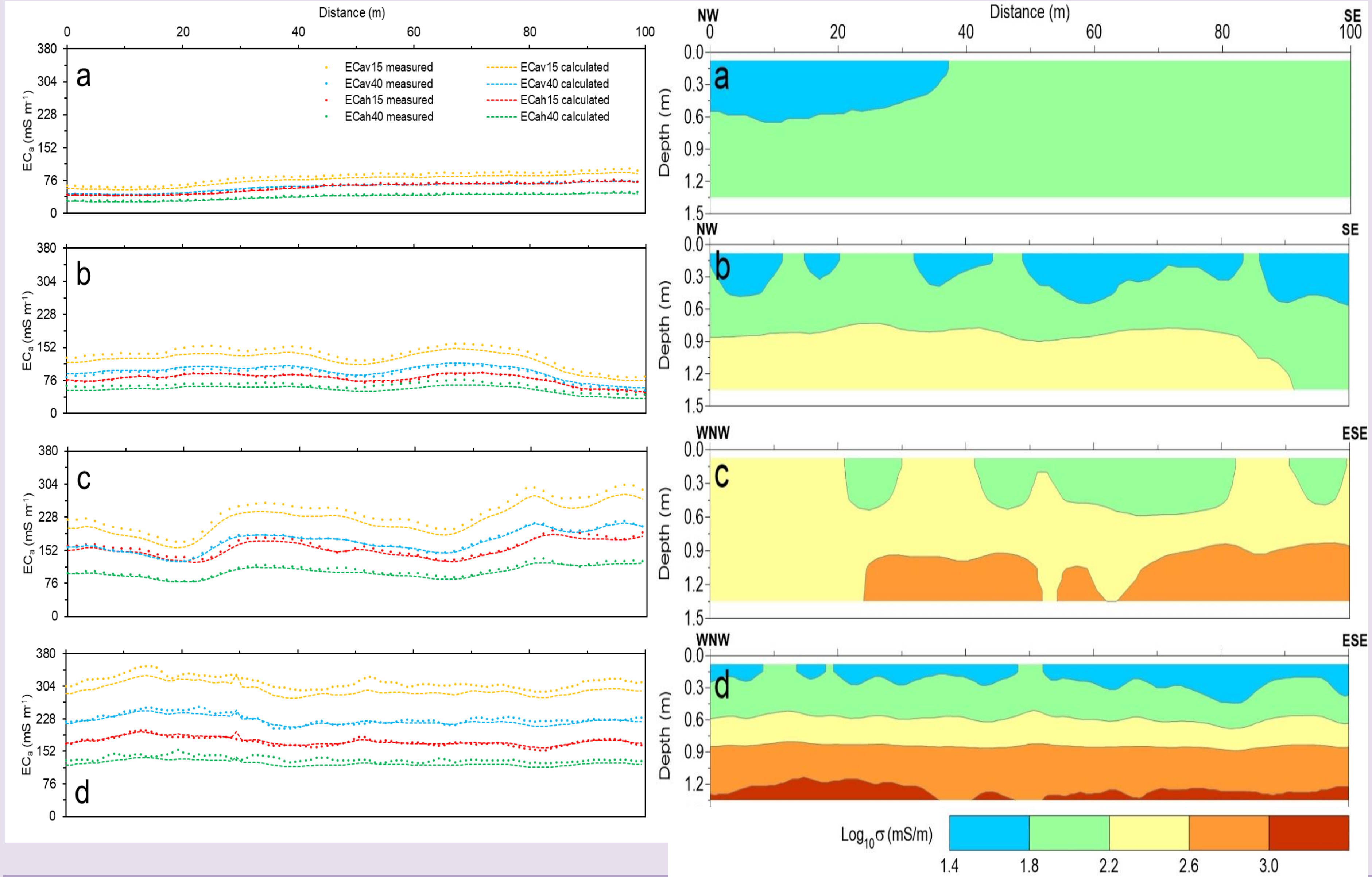
Triantafilis, J. and Monteiro Santos, F.A., Electromagnetic conductivity imaging (EMCI) of soil using a DUALEM-421 and inversion software

Experimental design- Portugal

- Four locations (1, 2, 3 and 4), were selected in a north-south orientation in Lezíria.
- Crops: Tomato (1), maize (2 and 3), pasture (4)
- EM38 readings: EMh, EMv (10 and 40 cm)- and ERT- Time-lapse measurments during 2 years
- 10 boreholes at each location in the first campaign.1-3 boreholes in the next campaigns at each location
- Soil sampling: 5 depths (0.3, 0.6, 0.9,1.2,1.5 m)



ECa maps



Distance (m)
a
b
c
d
ECav15 measured
ECav40 measured
ECah15 measured
ECah40 measured
ECav15 calculated
ECav40 calculated
ECah15 calculated
ECah40 calculated
EC_a (mS m^{-1})
0
76
152
228
304
380
0
20
40
60
80
100
NW
SE
WNW
ESE
Depth (m)
0.0
0.3
0.6
0.9
1.2
1.5
$Log_{10}\sigma$ (mS/m)
1.4
1.8
2.2
2.6
3.0

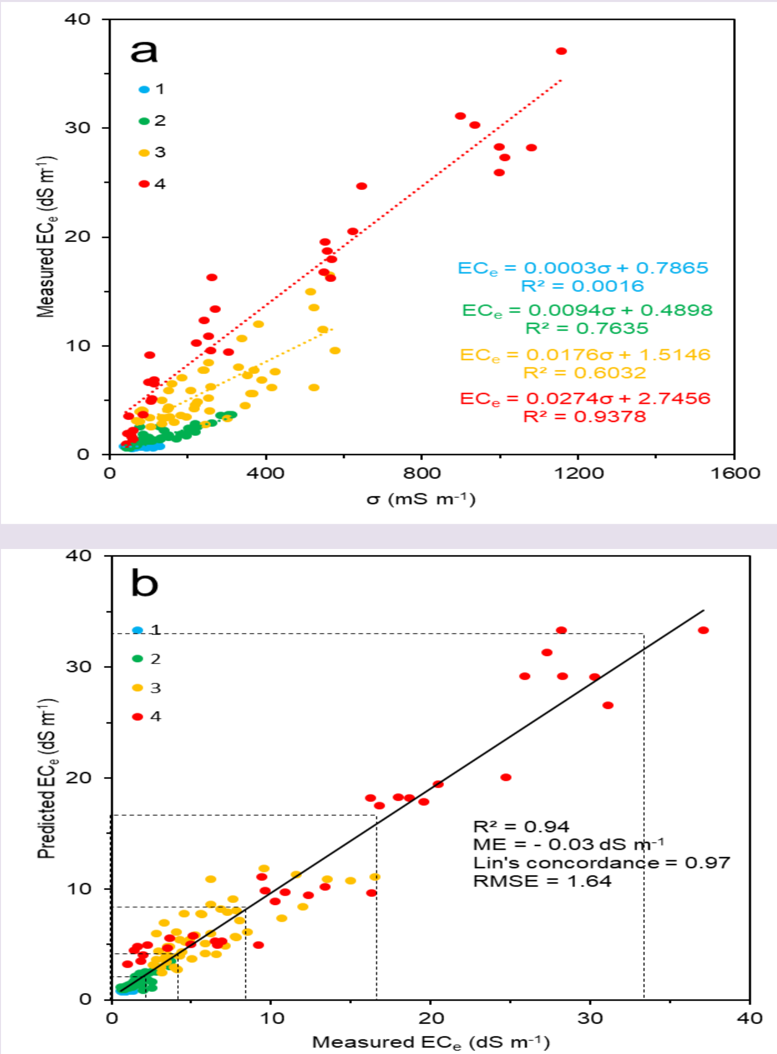
Soil sampling and Labratory analysis

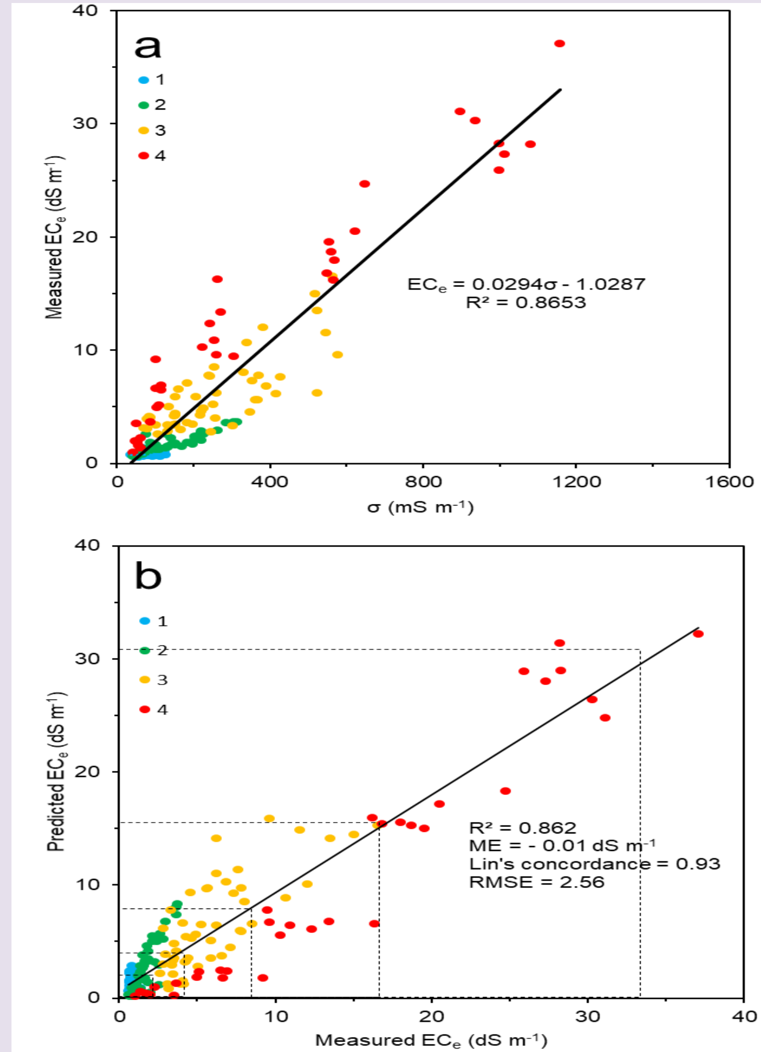
Soil saturation paste extract (EC_e),
Sodium adsorption ratio (SAR),
pH,
Cation exchange capacity (CEC),
Exchangeable sodium percentage (ESP),
Volumetric water content (θ),
Particle size distribution.

The classification presented in Table below was used as a base to classify the soils according to salinity and sodicity.

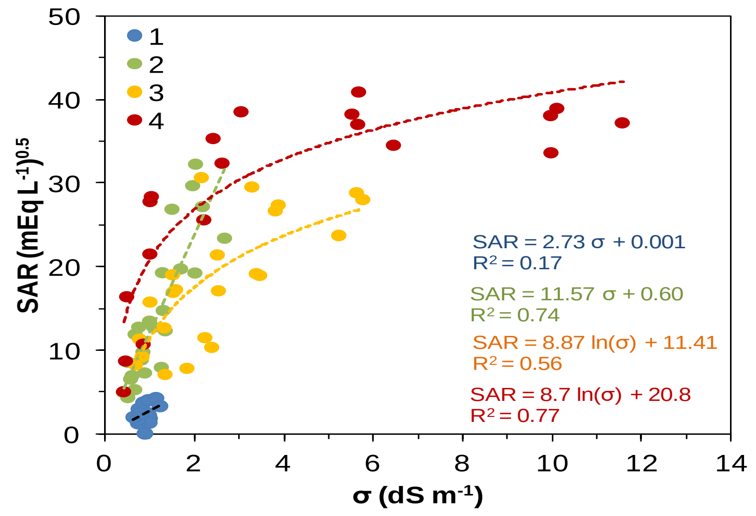
Soil classification	EC_e	SAR	ESP	pH
	$dS\ m^{-1}$	$(mEq\ L^{-1})^{0.5}$	%	
Non-saline and non-sodic	< 4	< 13	< 15	< 8.5
Saline-sodic	≥ 4	≥ 13	≥ 15	≤ 8.5
Saline	≥ 4	< 13	< 15	< 8.5
Sodic	<4	≥ 13	≥ 15	> 8.5

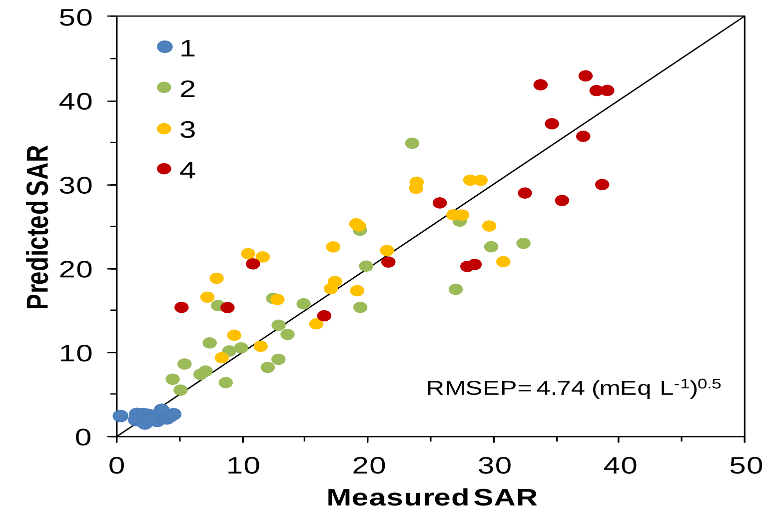
Site-specific ECe-σ vs regional ECe-σ Calibration

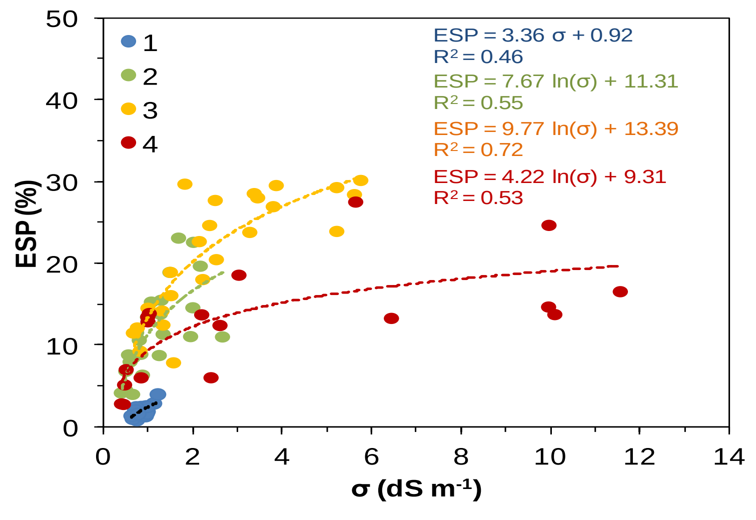


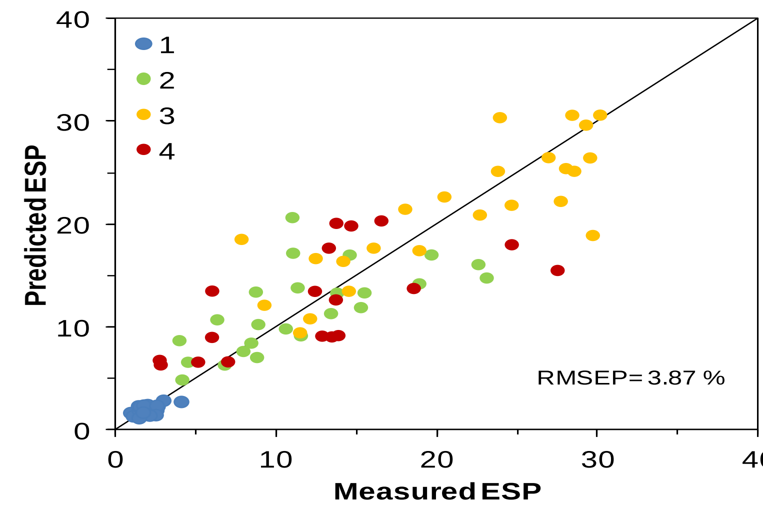


Site-specific SAR-σ and ESP-σ Calibrations

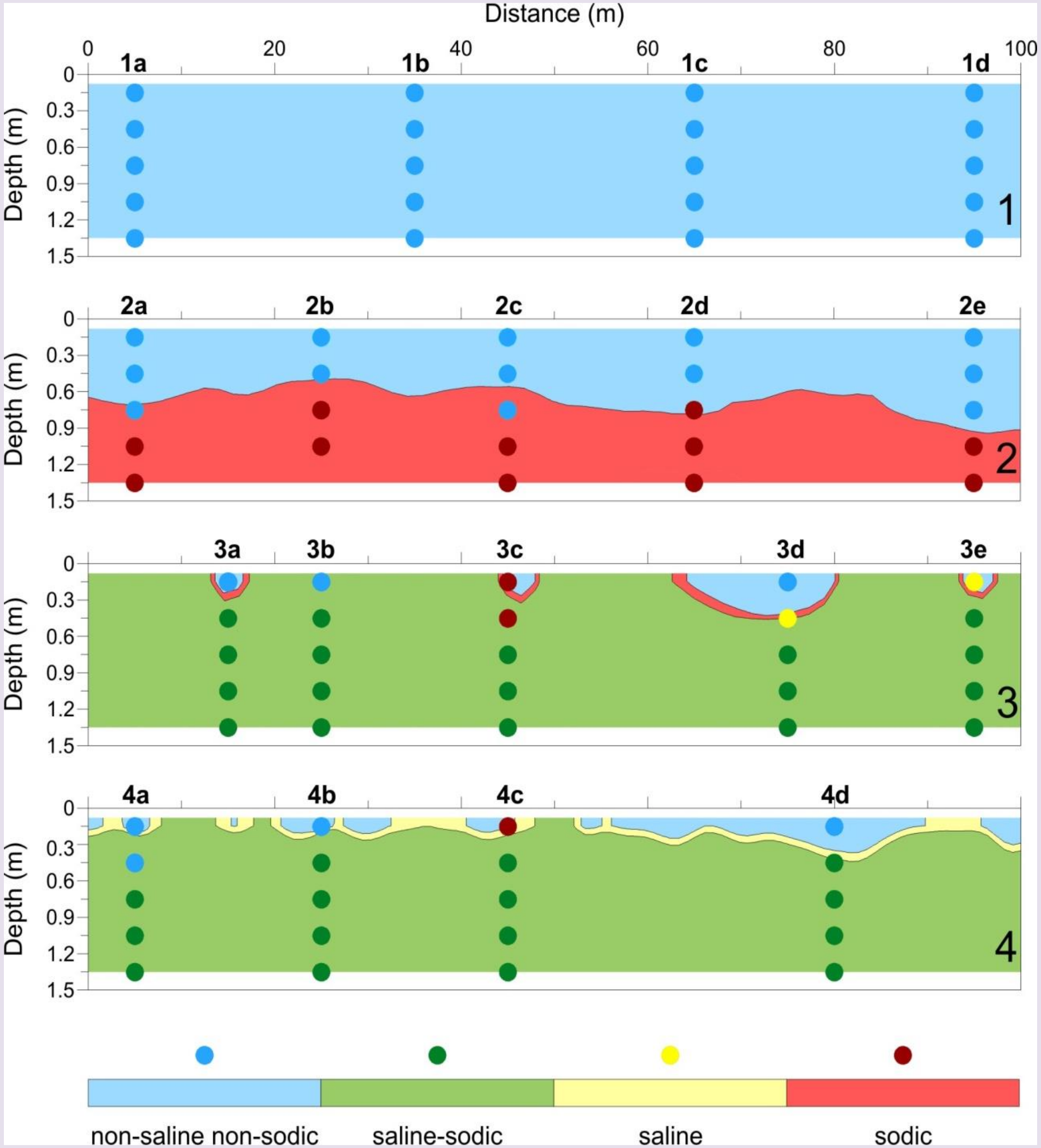








2-D maps of soil salinity classification



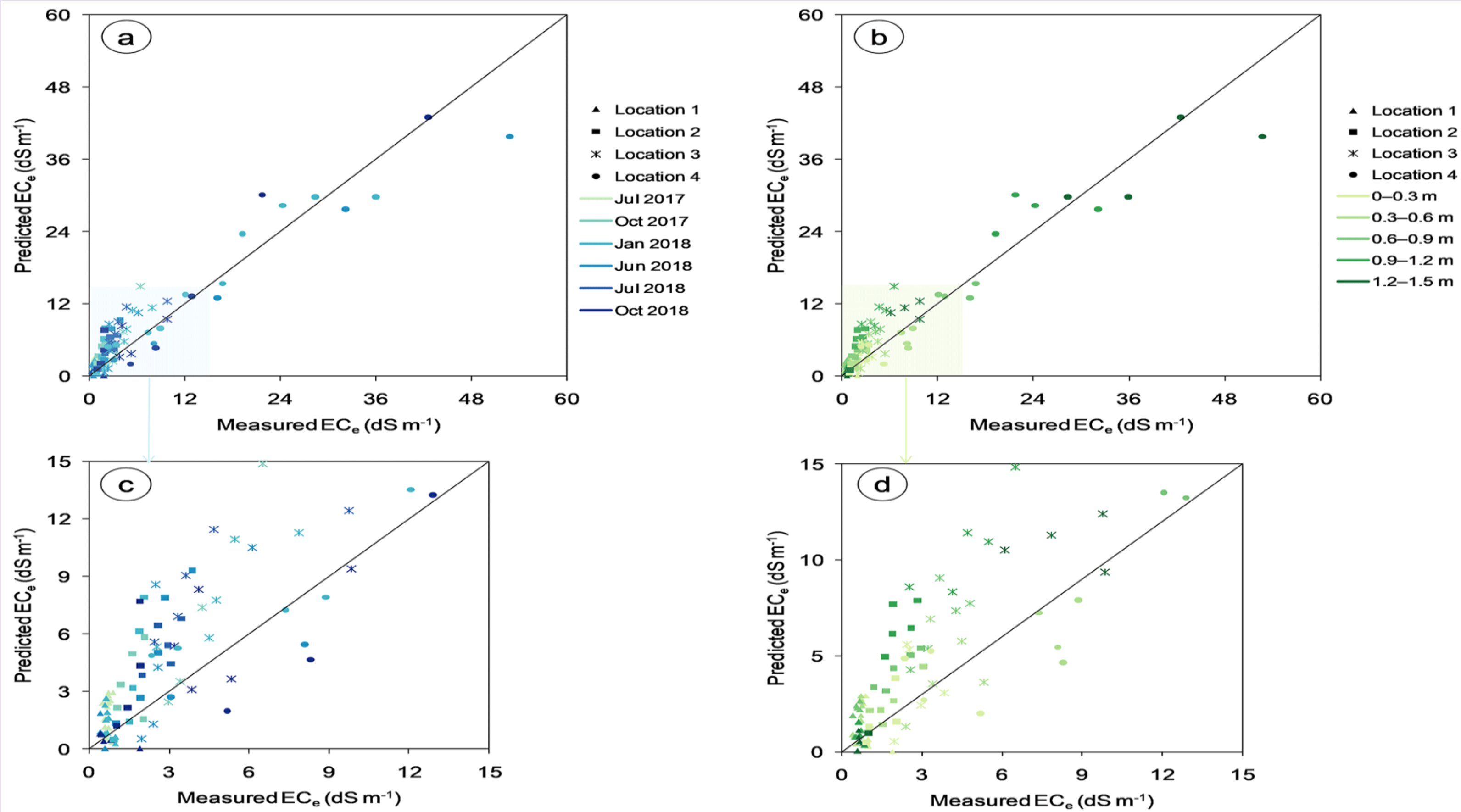
The circles represent the actual classification obtained from EC_e, SAR, and ESP measured at each sample.

There is generally good agreement between the predicted classification and the actual classification obtained from the samples, with 88.6% of the samples correctly classified.

Some samples were not correctly classified mainly at the top-soil and upper. These misclassifications occur mainly in layers with a change in the classification at the neighbouring layer.

The classification error could be due to the variability within the layer, as the sample is taken at the middle depth for each layer. It could also be a result of the effects of smoothing from the regularization applied in the inversion algorithm, which can smooth the sharp changes that occur between layers. In addition, the four EC_a measurements can be insufficient for recovering sharp variability of σ with depth.

Temporal validation of the regional ECe-σ



	RMSE (dS m^{-1})	ME (dS m^{-1})	Lin's CCC	R^2	EC_e min (dS m^{-1})	EC_e max (dS m^{-1})	EC_e range (dS m^{-1})	Number of data
Global	3.14	−1.23	0.94	0.88	0.35	52.70	52.35	103
Jan 2018	2.79	−1.33	0.96	0.91	0.59	35.90	35.31	30
Jun 2018	4.27	−0.08	0.94	0.90	0.35	52.70	52.35	20
Oct 2018	3.11	−0.71	0.96	0.91	0.44	42.50	42.06	19

Challenges

Insufficient data for σ mapping	⇨	Using multiple-coils sensor / collecting multi-height data
Inverting time-lapse data	⇨	Developing a time-lapse inversion algorithm
Best Inversion parameters	⇨	Performing hydrological modelling/ synthetic tests Available site information
Electromagnetic sensor drift	⇨	EC_a calibration using TDR, ERT, inversion\model response
σ / soil properties relationship	⇨	In-situ calibration

Conclusion

Inversion of **multi-heights/multiple-coils** data can be used to image **soil electrical conductivity** with **depth.**

Soil electrical conductivity images can be converted to **soil salinity and sodicity** using an in-situ site calibration when there is a strong correlation between soil electrical conductivity and soil salinity.

Paz, A., Castanheira., N., Farzamian, M., Paz, M.C., Gonçalves, M., Monteiro Santos, F., and Triantafilis, J. 2020. Prediction of soil salinity and sodicity using electromagnetic conductivity imaging. ***Geoderma, 361, 114086.***

The prediction ability of the location-specific and regional calibration approaches in terms of soli salinity prediction is comparable. The location-specific calibration resulted in slightly better overall prediction; however, the regional calibration can be used at any location on the peninsula within the range of the measured ECe.

Farzamian, M., Paz, M.C., Monteiro Santos, F., Gonçalves, M.C., Paz, A.M., Castanheira., N.L., Triantafilis, J. 2019. Mapping soil salinity using electromagnetic conductivity imaging – a comparison of regional and location-specific calibrations. ***Land Degradation and Development 30, 1393–1406***

Repeated EM data along the same transects can be used to monitor salinity with time. However, variations of other parameters (i.e. Moisture content, groundwater level) make it difficult to assess the dynamic of soil salinity.

Paz, M. C., Farzamian, M., Paz, A. M., Castanheira, N. L., Gonçalves, M. C., and Monteiro Santos, F.: Assessing soil salinity dynamics using time-lapse electromagnetic conductivity imaging, ***SOIL, 6, 499–511.***

The **time lapse** inversion algorithm can improve temporal salinity mapping. Repeating EMI surveys after irrigation will allow also to better study the dynamic of soil salinity as the water content distribution will not change significantly, and the sensitivity of σ to the wet salinity in wet soils is higher.

Farzamian, M., Autovino, D., Basile, A., De Mascellis, R., Dragonetti, G., Monteiro Santos, F., Binley, A., and Coppola, A. 2021: Assessing the dynamics of soil salinity with time-lapse inversion of electromagnetic data guided by hydrological modelling, ***Hydrol. Earth Syst. 25, 1509–1527.***

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