Regional calibration and electromagnetic conductivity imaging for assessing the dynamics of soil salinity

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How?

1) Use of electromagnetic induction (EMI), a near-surface geophysical technique, to measure the soil apparent electrical conductivity (ECa, mS m^{-1}) over an area.

2) Inversion of ECa to obtain electrical conductivity imaging (EMCI), which provides the spatial distribution of the soil electrical conductivity (σ, mS m^{-1}).

3) Calibration process consisting of a regression between σ and the electrical conductivity of the saturated soil paste extract (ECe, dS m^{-1}), used as a proxy for soil salinity.

4) Conversion of EMCI into salinity maps or cross sections using the obtained calibration equation.

Where?

Lezíria Grande de Vila Franca de Xira, hereafter called Lezíria, is an important agricultural sytem located in Portugal. This is a peninsula of alluvial origin surrounded by the Tejo and Sorraia rivers and the Tejo estuary. Here, soil faces risk of salinization due to climate change, as the level and salinity of groundwater are likely to increase as a result of the rise of the sea water level and consequently of the estuary. These changes can also affect the salinity of the irrigation water which is collected upstream of the estuary. Land use in this area (of about 130 km^2) is constituted by irrigated annual crops in the northern part and mainly by rainfed pastures in the southern part.

Figure 1. A pasture field in Lezíria. Horses are one of the animal species raised here.

Data

Field campaigns were carried out between May 2017 and October 2018 at four locations with different salinity levels across the study area. Geophysical data was acquired with a EM38 from Geonics, and was inverted using EM4Soil software. ECe was measured with a conductivity meter (WTW 1C20-0211 inoLab) in the extract collected from the soil saturation paste obtained from 300 g of air-dry soil samples.

We used the data collected at the first date, at all locations, to do the calibration process, obtaining a regional calibration (RC), and the data collected posteriorly to evaluate the ability of the regional calibration to predict soil salinity, through the calculation of root mean square error (RMSE), mean error (ME), Lin's concordance correlation coefficient (Lin's CCC), and coefficient of determination (R^2).

The transitory nature of data also allowed to perform a qualitative analysis of the soil salinity dynamics.

Figure 2. Data collection in the field, using the EM38, and soil sampling device (first and second photos); soil treatment for calculation of parameters in the laboratory (third photo).

Figure 3. Map of Lezíria Grande de Vila Franca de Xira, here called Lezíria, showing the main geographical features.

Remarks

Prediction ability of our RC does not vary significantly over time, so it is an expeditious method to predict soil salinity from EMI surveys at any new location in the study area. However, significantly larger variations of ECe and σ at location 4 dominated the regional regression calibration, which means the RC has good prediction ability in the south of the study area and close to location 4, where the soil salinization is of major concern and can compromise agricultural activity.

The obtained salinity cross sections show a qualitative response of soil salinity to the input of salts and water either through irrigation, precipitation, or level and salinity of groundwater.

In a regional perspective, soil salinity dynamics in Lezíria may be preliminarily explained by a combination of spatial distribution of the marine fraction of soil, with irrigation practices and saline groundwater in the southern part.

Figure 4. Cross sections of soil salinity for the four locations, with representation of measured ECe (circles) and groundwater level (black triangles) at the sampling site in the middle of each transect. Note that location 4 is not irrigated.

Abstract EGU21-16296, based on the research published in the following papers:

10.5194/soil-6-499-2020

10.1002/vzj2.20017

Acknowledgements
Thanks to the Polytechnic Institute of Setúbal for financing vEGU2021 attendance.
Special thanks to Dorothée Post for her vEGU2021 poster design workshop and Nuno Barreiras for map support.
The research work was financed by Fundação para a Ciência e a Tecnologia (grant nos. ARIMNET2/0004/2015, ARIMNET2/0005/2015, and PTDC/ASPSOL/28796/2017).

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