TERENO
TERRESTRIAL ENVIRONMENTAL OBSERVATORIES
OZCAR
CRITICAL ZONE OBSERVATORIES : RESEARCH AND APPLICATIONS

Electrical resistivity applications for supporting precision agriculture: a promising approach also for environmental monitoring?

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Uni ct AGRICOLTURA, ALIMENTAZIONE E AMBIENTE

26 September 2023, Bonn

About me:

Uni ct AGRICOLTURA, ALIMENTAZIONE E AMBIENTE

TERENO OZCAR International Conference 25-28 Sept 2023, Bonn

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Monday from 15:00 to 17:00 | Wednesday from 11:00 to 13:00 via MicrosoftOffice Team (codice yto8oqf), please send an e-mail to arrange an appointment in other time slots and/or days

My research line is focused on the agricultural sustainable management of the soil and water resources, with a special emphasis to the identification of **minimally invasive** and **multi-scale approaches for monitoring** and **modelling** the transfer processes acting within the **soil-plant-atmosphere *continuum***.

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Contents:

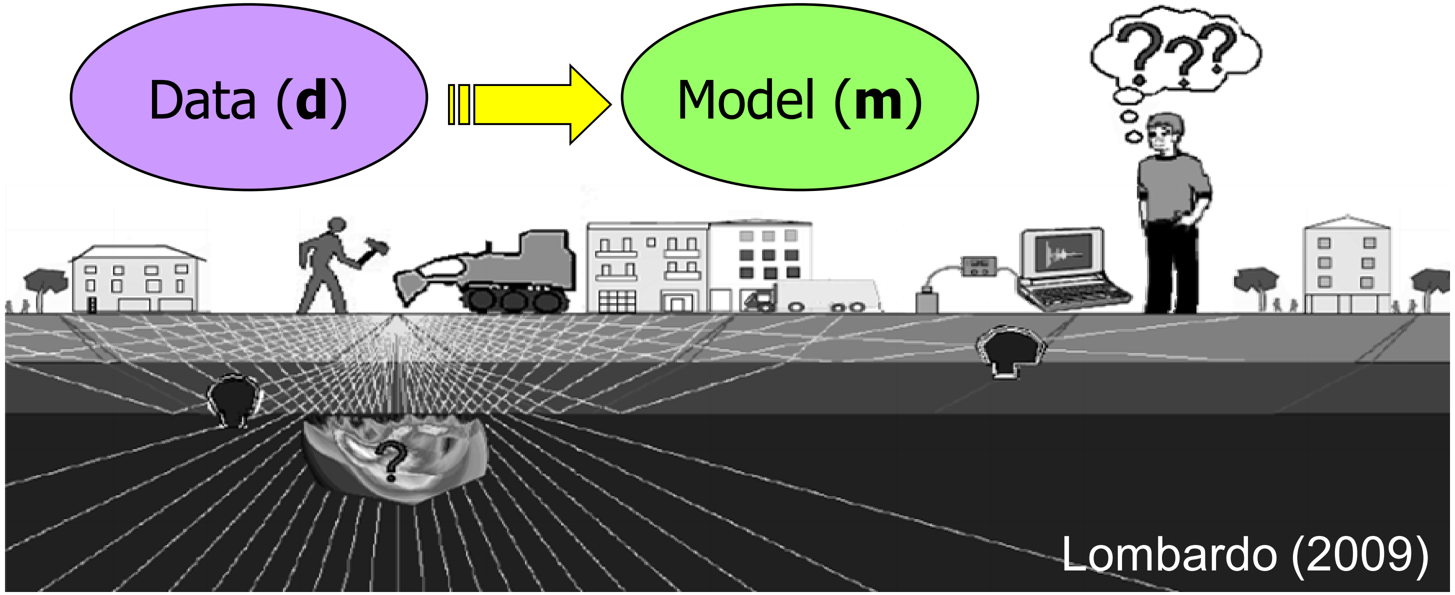
- Basics of geophysical methods
- Electrical resistivity basic principles
- Electrical resistivity tomography (ERT) technique
- Case studies in Sicily (Italy):
  orange orchards under different **sustainable water and soil management practices**
- Case studies in California (USA):
  almond orchards treated with **organic amendments**

Purpose:
Show soil-plant-water-related applications of geophysics in agricultural contexts

- Conclusive remarks

Basics of geophysical methods:

It is typical of geophysical methods to obtain **indirect information** about the **soil properties** from the analysis of one or more **variables** that characterize the **geophysical field** of interest.



Lombardo (2009)

This approach calls for carrying-out measurements using **sources** and **sensors** that are placed around the desired area or volume of interest.

The derived geophysical information are then modelled applying the mathematical formulation of the so-called inverse problems.

Main physical properties from geophysical methods:

- Geo-electrical surveys: electrical resistivity (or electrical conductivity)
- Electromagnetic induction methods: electrical conductivity
- Ground penetration radar: permittivity, electrical conductivity
- Self-potential methods: electrical conductivity, electrical sources
- Induced polarization: complex electrical conductivity, chargeability
- Seismic methods: elastic modules and density
- Magnetrometry methods: remnant magnetism or magnetic susceptibility
- Gravimetric methods: density

Main physical properties from geophysical methods:

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Hydrogeophysical applications

Hydrogeophysical techniques: spatial resolution and scale of application

In situ | Lab-meas.

Soil proprieties *vs* state variables (i.e, moisture content)

- Static
- Time lapse

Geophysical tecniques

+

Hydrological application

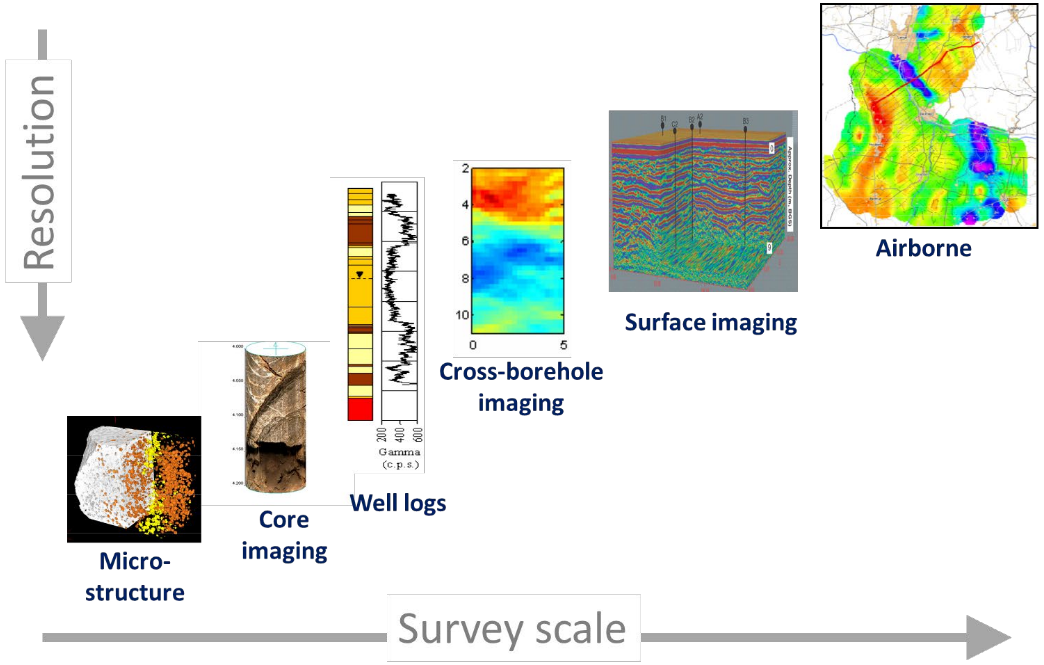
- Large scale
- Small scale

Catchment
Hillslope
Aquifer
Vadose zone
Root zone

Flow in unsutared and satured soil
Solute trasport
Root water uptake ???

HYDRO-GEOPHYSICS

(*Rubin and Hubbard*, 2005; *Vereecken et al.*, 2006; *Binley et al.*, 2011)

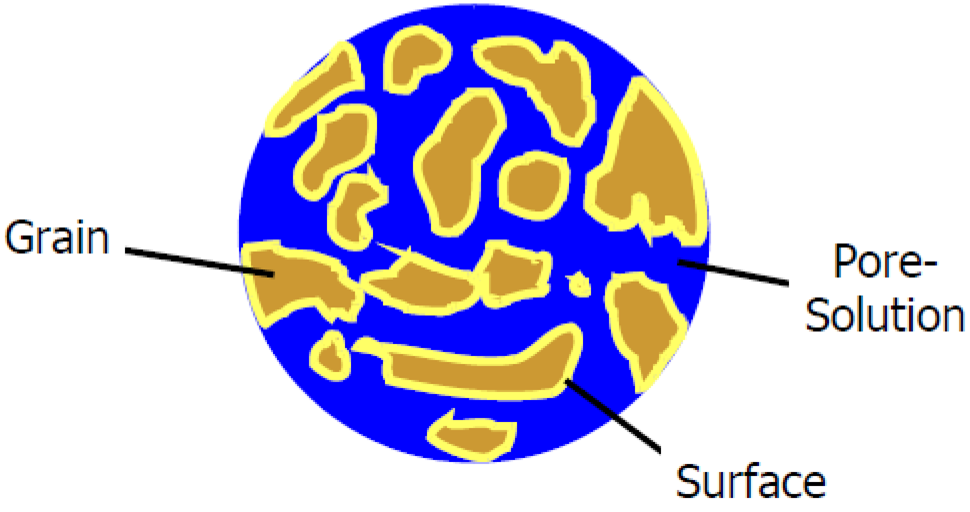


Electrical resistivity basic principles:

Electrical resistivity (ER) methods permit to derive the soil spatial ER characteristics at low frequency.

These characteristics maily depend on:

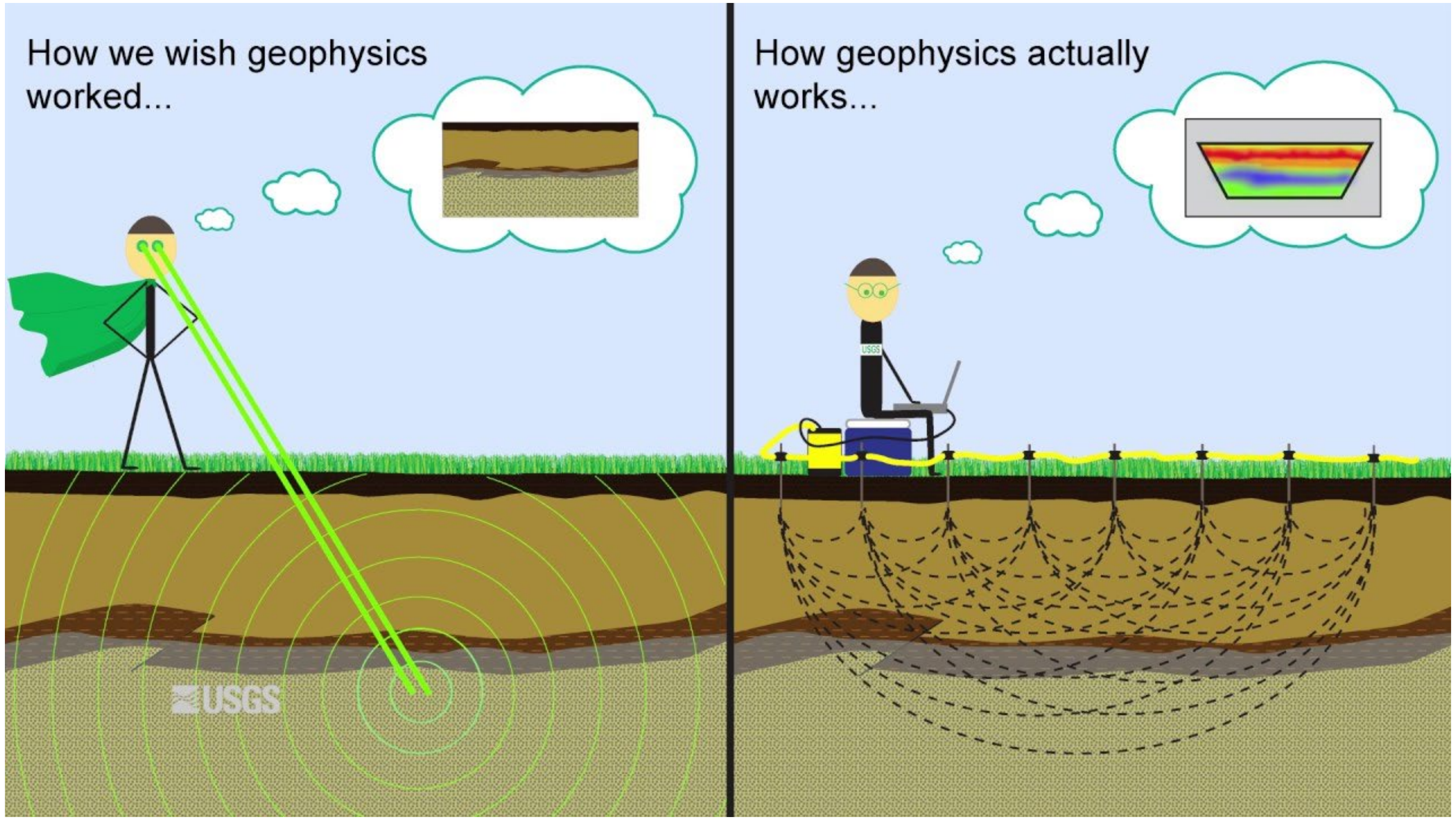
- soil type,
- soil pore solution,
- water content



Electrical Transport = Flow + Storage

Electrical resistivity basic principles:

ER methods inject an electrical current (**I**) into the soil through current electrodes (C+ and C-) and the difference in current flow potential (**ΔV**) is measured at potential electrodes (P+ and P-) that are placed in the vicinity of the current flow (**Ohm's Law**).



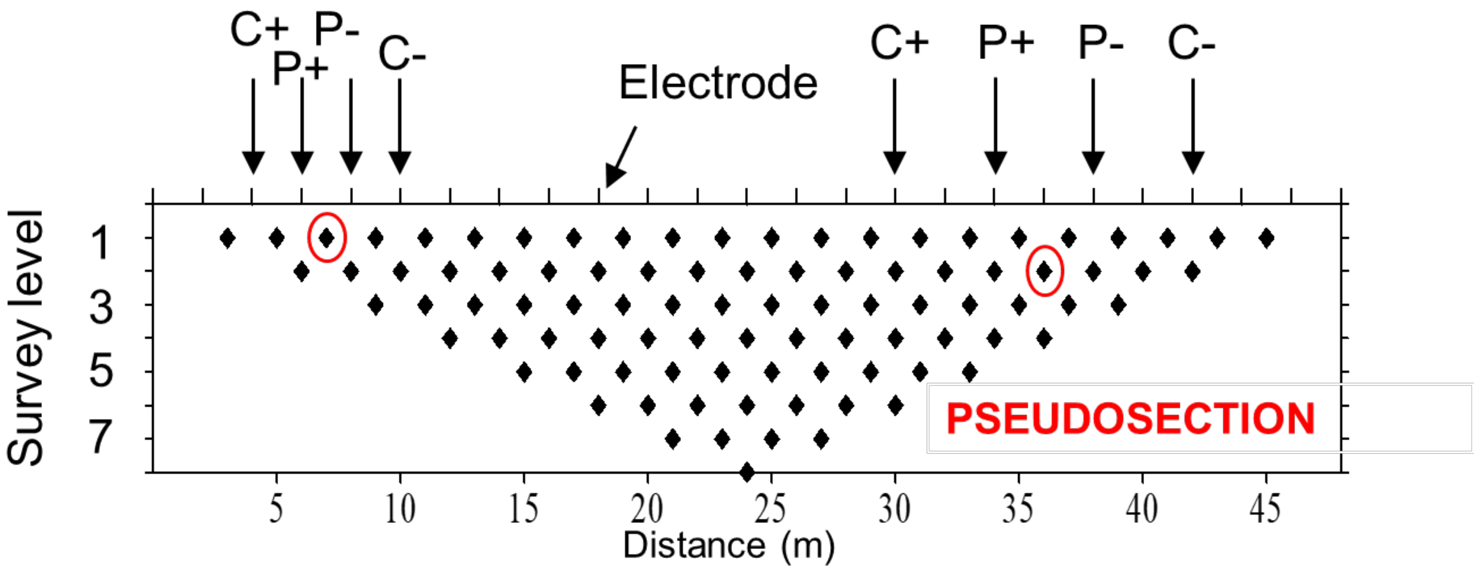
$$\rho = k\frac{\Delta V}{I}$$

k = geometric factor
ρ = ER (Ω m^{-1})

Electrical resistivity tomography technique:

The development of multi-electrode equipment made possible to depict 2D and 3D sections of subsurface ER using the **electrical resistivity tomography** (ERT) technique.

In this way, different combinations of arrays are possible using the same sequence and varying the depth of investigation.



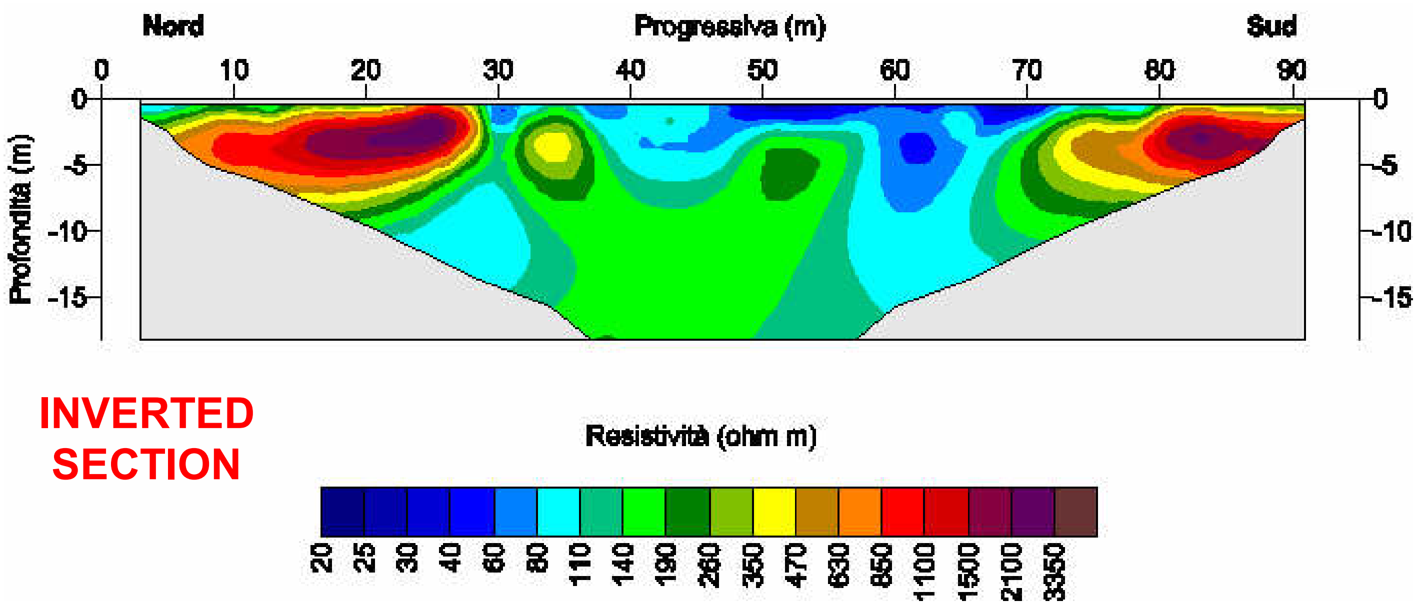
Electrical resistivity tomography technique:

Advantages:

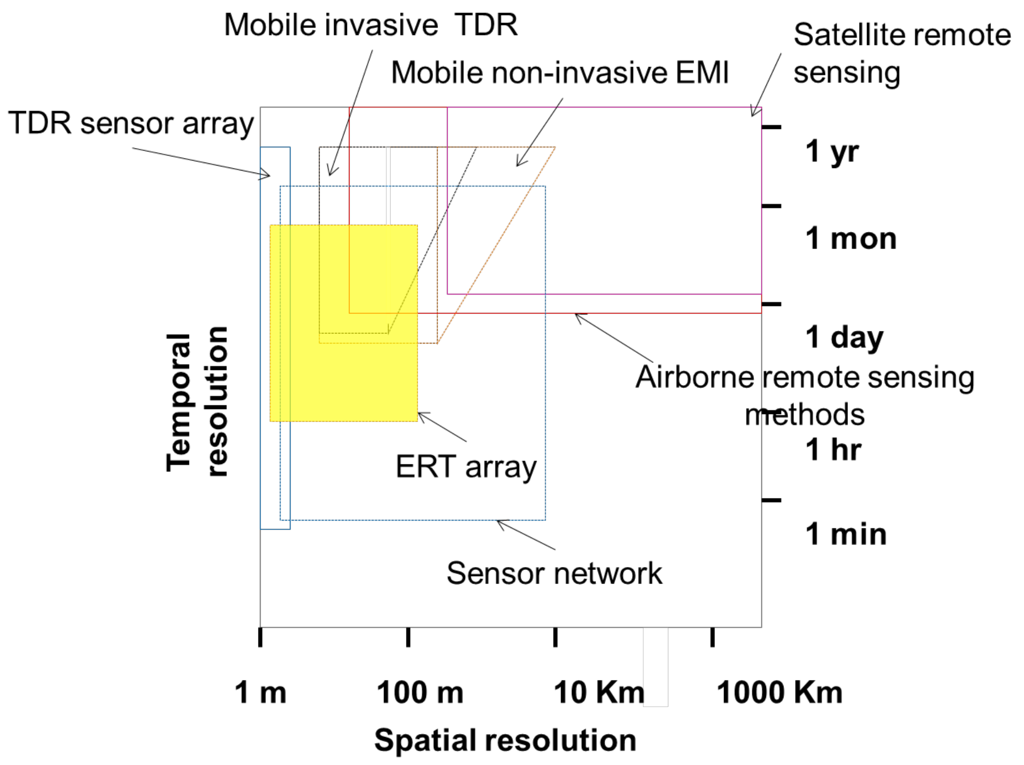
- To relate the ER changes to different state conditions (including soil water content and salinity)
- To provide great lateral coverage and depth of investigation

Limitations:

- To be sensible to surface heterogeneities
- To loose resolution with depth



INVERTED SECTION



Robinson et al., (2008)

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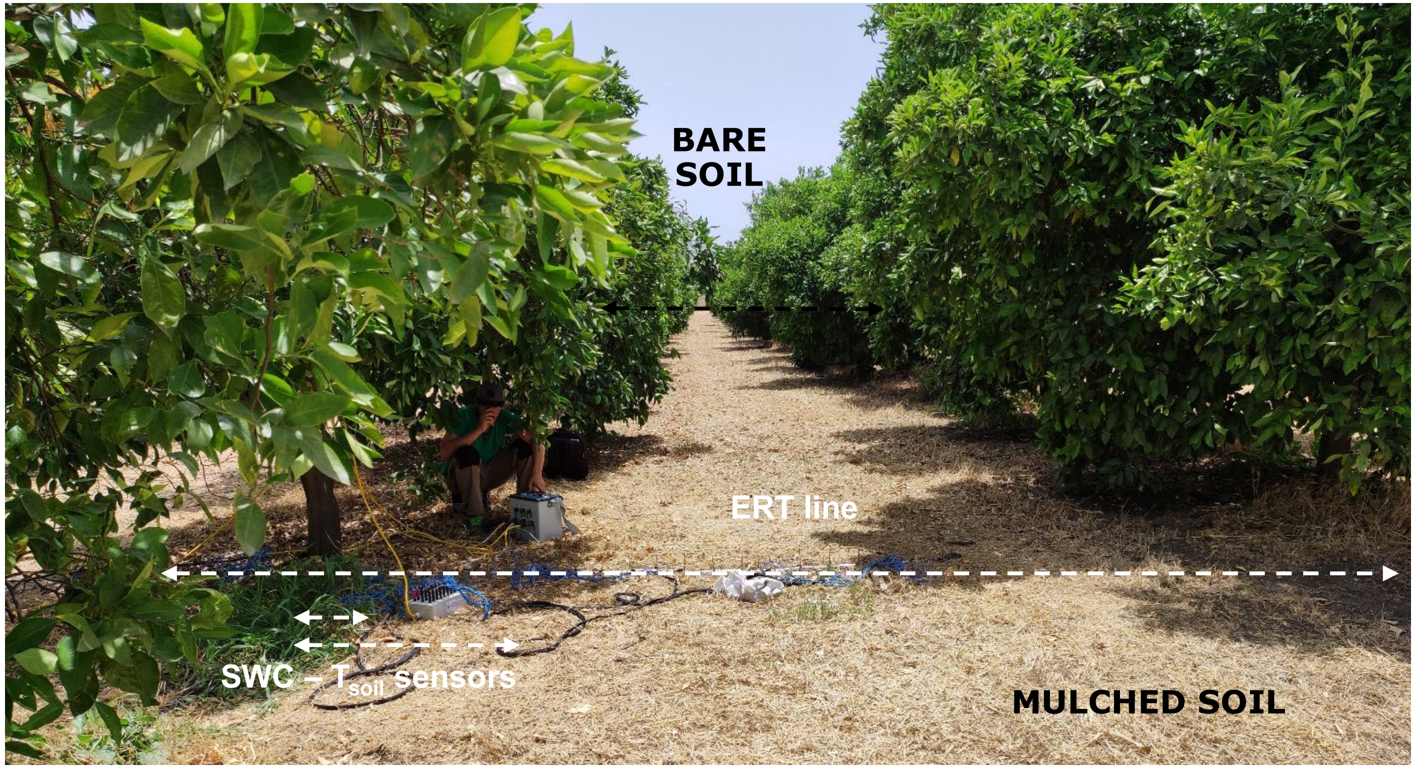
Sicilian case study 1 – Sustainable agricultural practices

Aims and materials and methods



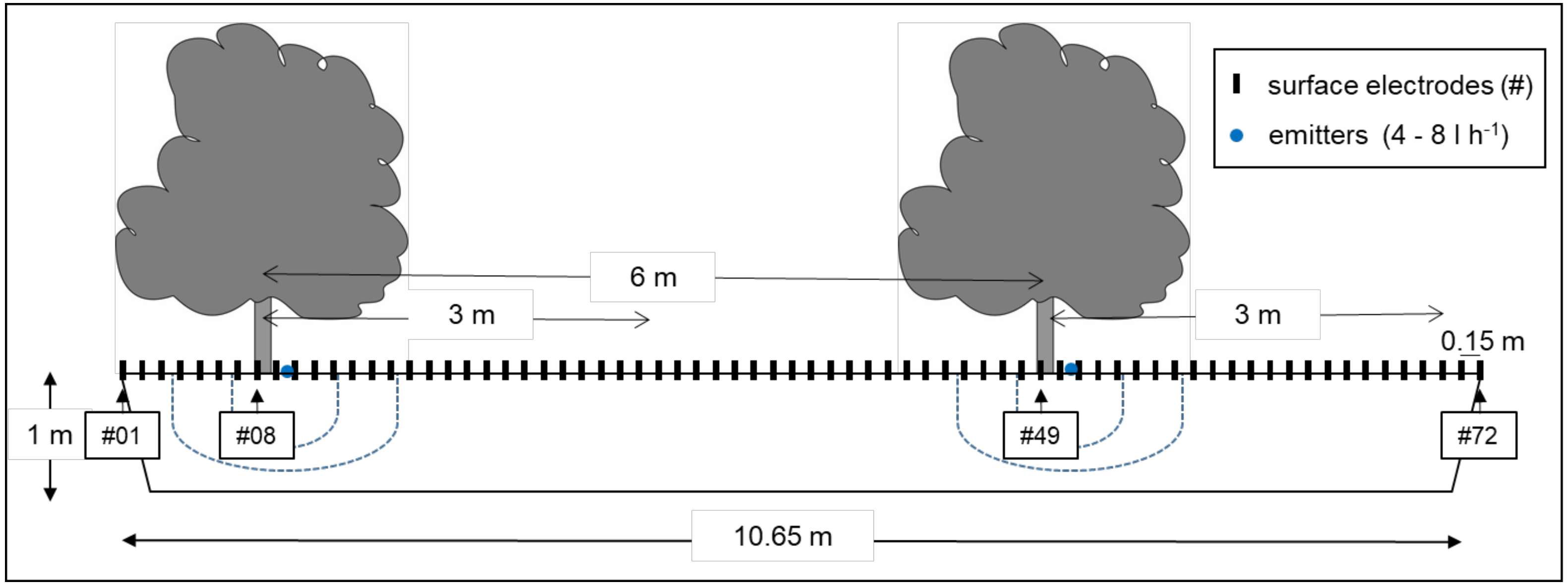
- To characterize the soil-plant interactions under sustainable soil and water management practices (i.e., full and regulated deficit irrigation (FI and RDI) with/without mulching (BARE and MULCH);
- To combine the ERT technique together with continuous point-based soil water content (SWC) measurements.

Sicilian case study 1 – Sustainable agricultural practices

ERT configuration applied for time-lapse acqusitions

Multiple ERT surveys were conducted on July and Sept., 2022. For each time-period, the ERT surveys were repeated in **time-lapse mode** within an irrigation cycle (before, during and at the end of the irrigation event).

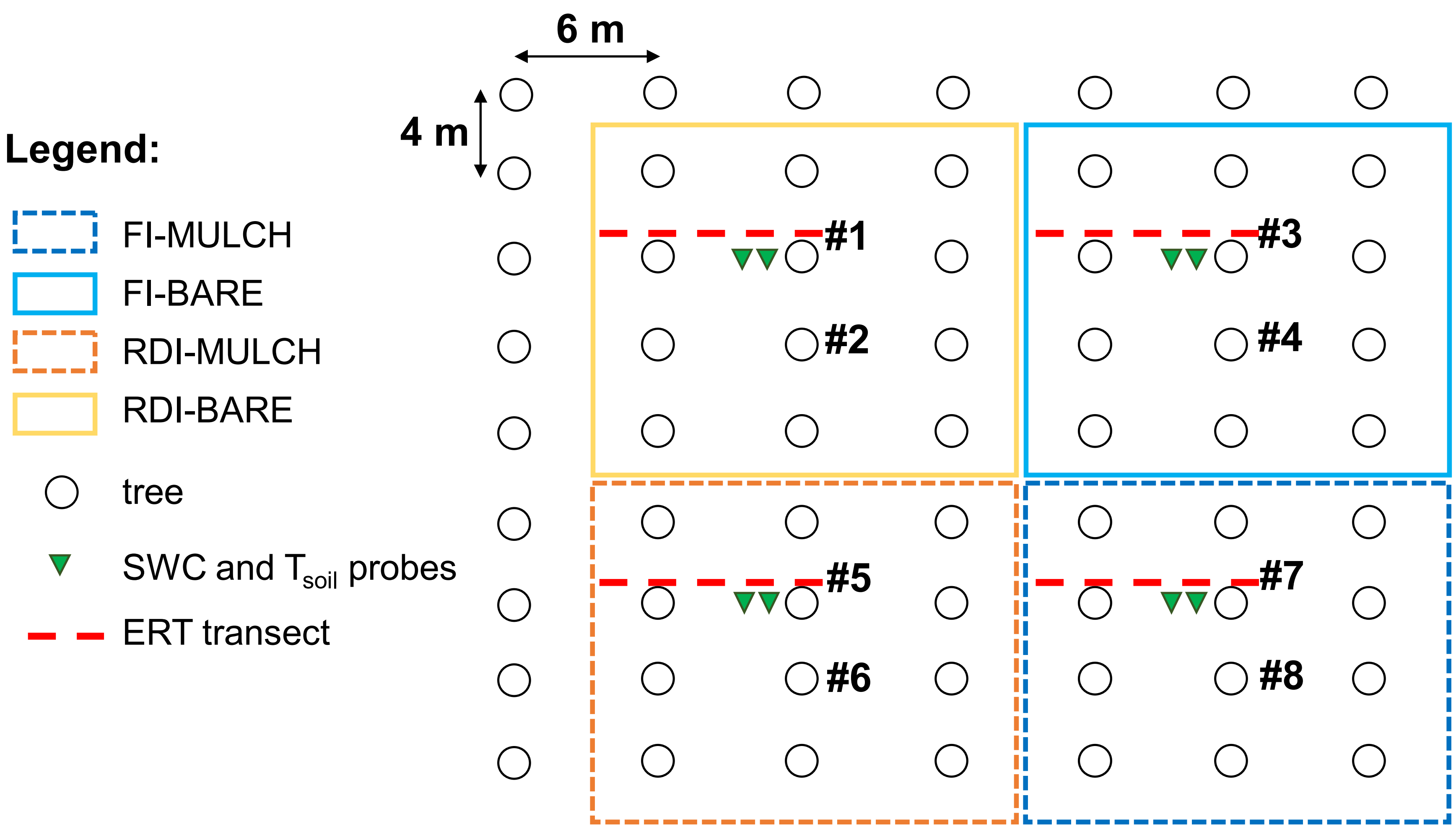
no irrigation condition	**time 00**
during and after the irrigation phase	time 01 time 02 … time n



Each ERT transect was displayed perpendicular to the tree lines, covering two trees. At least 1 emitter for tree was intercepted by each ERT transect.

Sicilian case study 1 – Sustainable agricultural practices

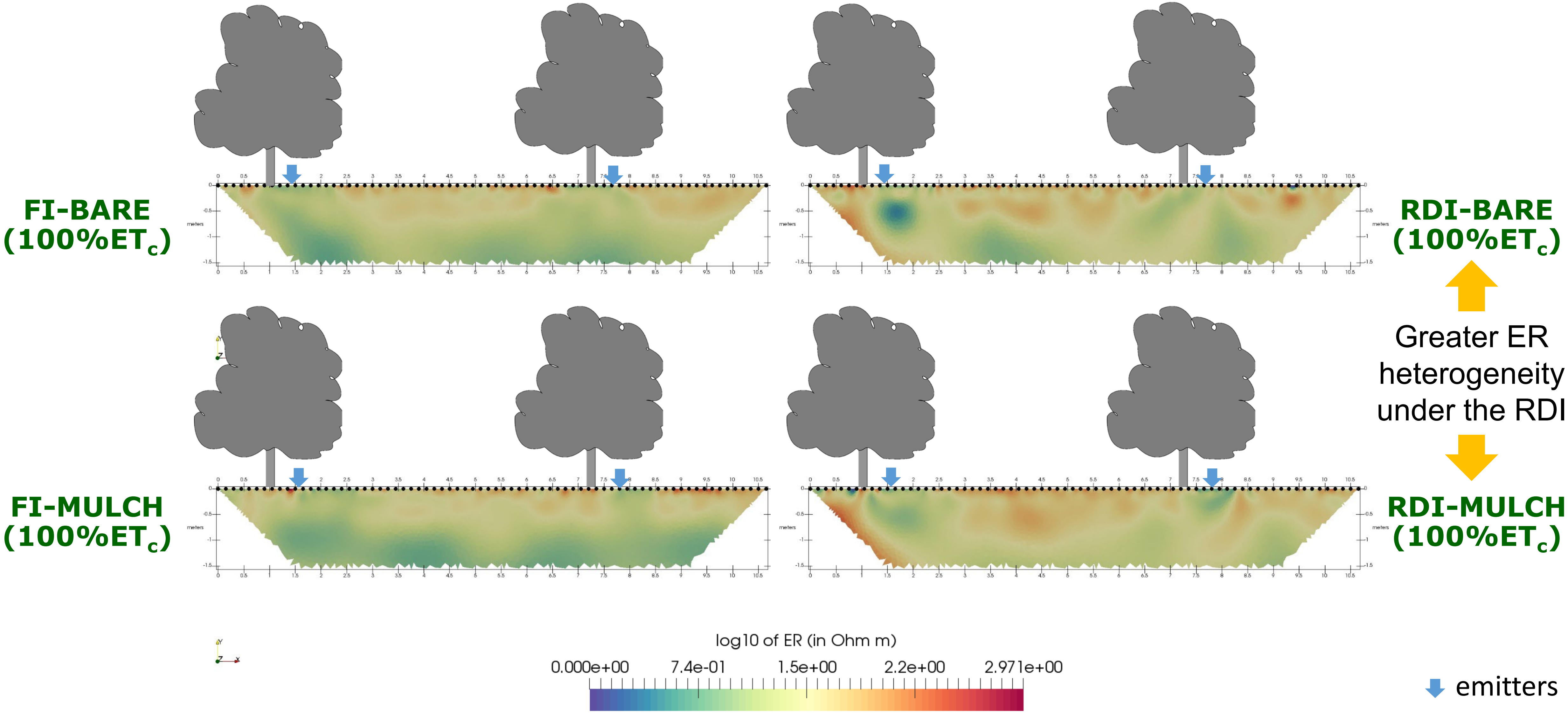
Overview of the ERT layout and sensors locations at treatment level



n. 2 sensors (TEROS-12, METER Group) installed at 30 cm from the soil surface and located at 2 distances from the tree trunk (i.e., 35 and 75 cm, respectively)

Sicilian case study 1 – Sustainable agricultural practices

Absolute ERT inversions: July, 2022 (before irrigation)



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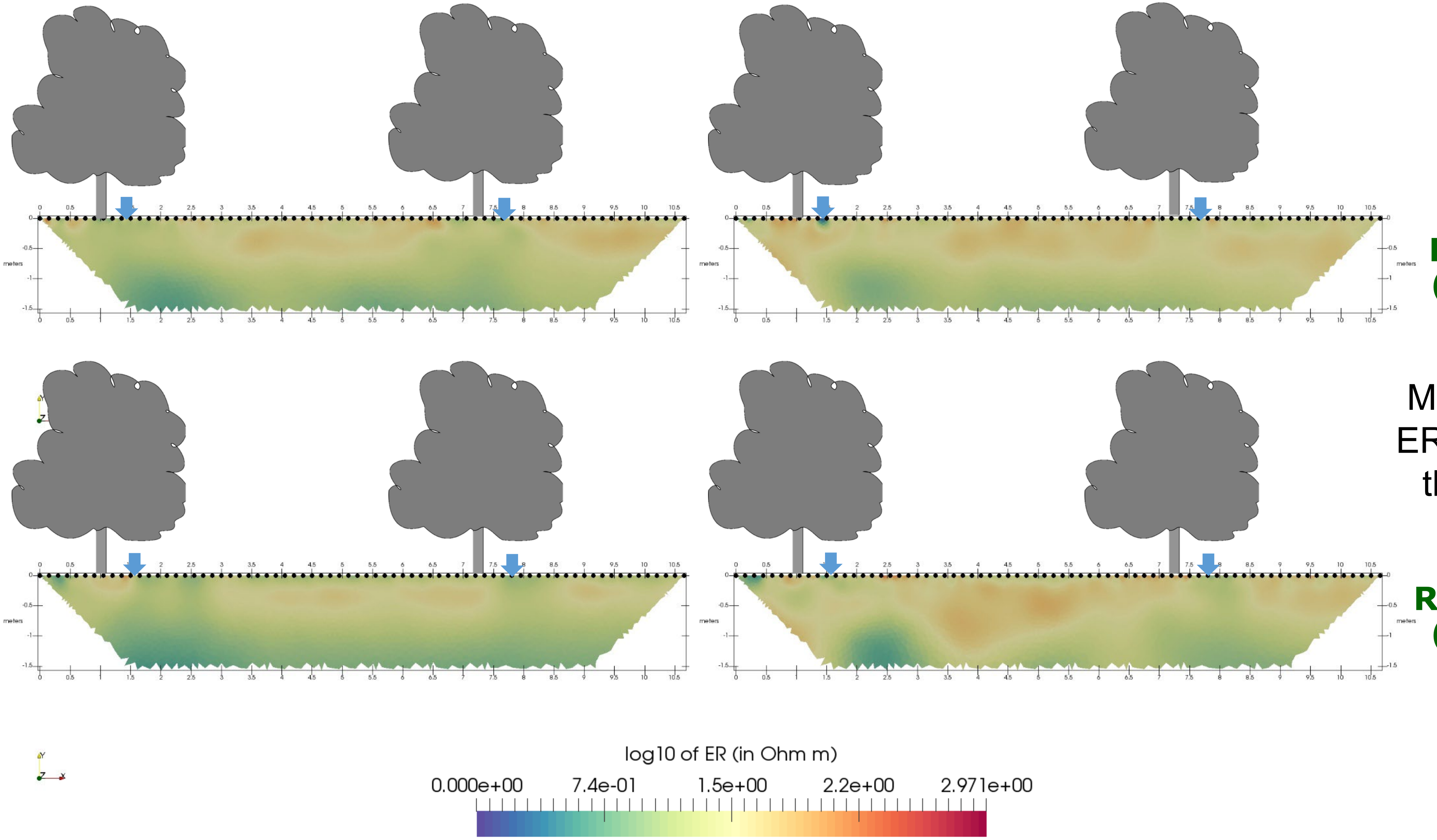
Absolute ERT inversions: September, 2022 (before irrigation)

FI-BARE (100%ET$_c$)

RDI-BARE (50%ET$_c$)

FI-MULCH (100%ET$_c$)

RDI-MULCH (50%ET$_c$)

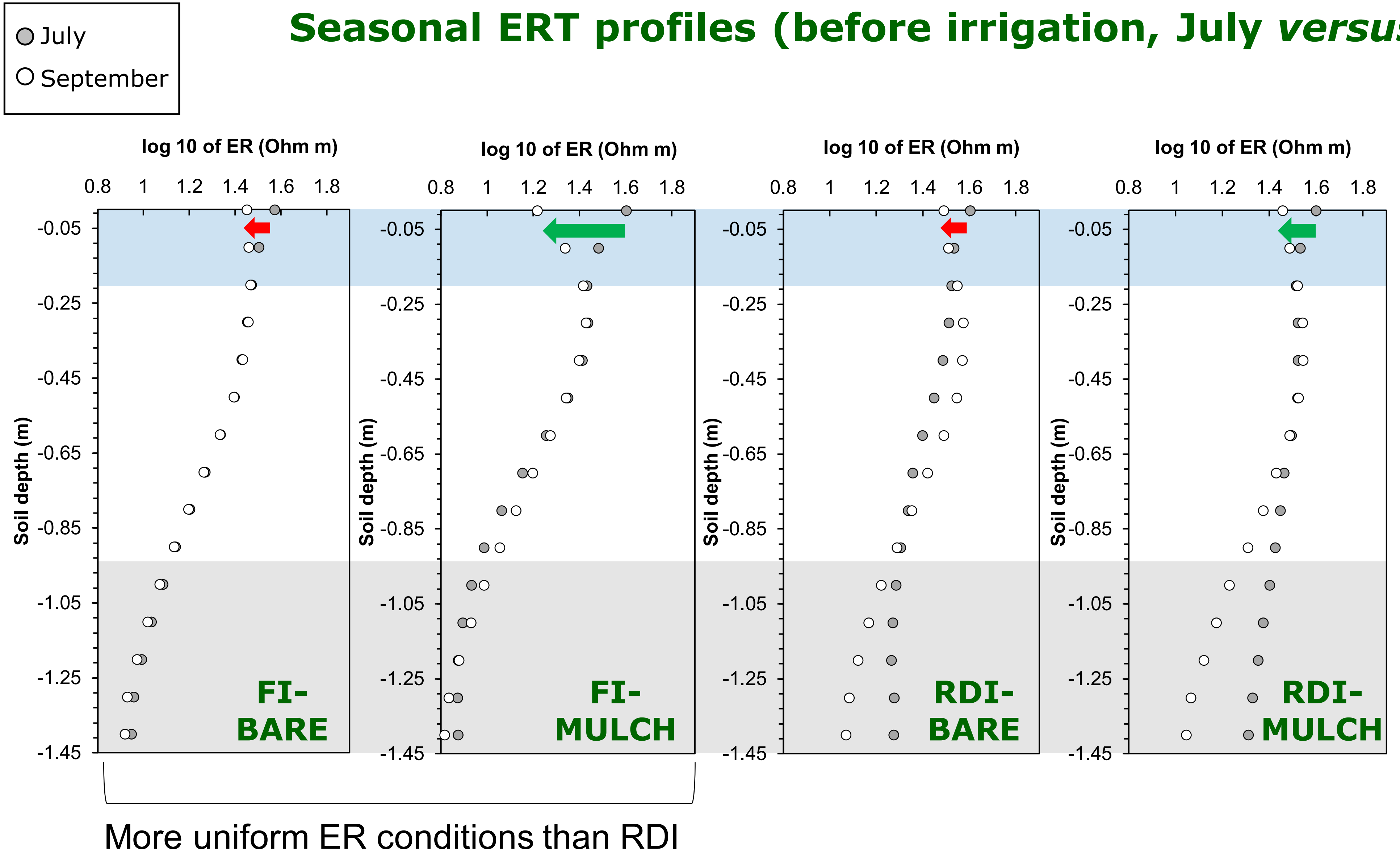


More uniform ER distribution than in July

emitters

Sicilian case study 1 – Sustainable agricultural practices

Seasonal ERT profiles (before irrigation, July *versus* Sept)



- Shallow soil layer (0-10 cm): more conductive in Sept. than July under mulched soils, especially at FI regimes;

Higher water retention and less evaporation?

- Middle part (20-90 cm): ER profiles tend to overlap eachother
- Deeper soil layers (-90 cm): more conductive than the upper soil layers.

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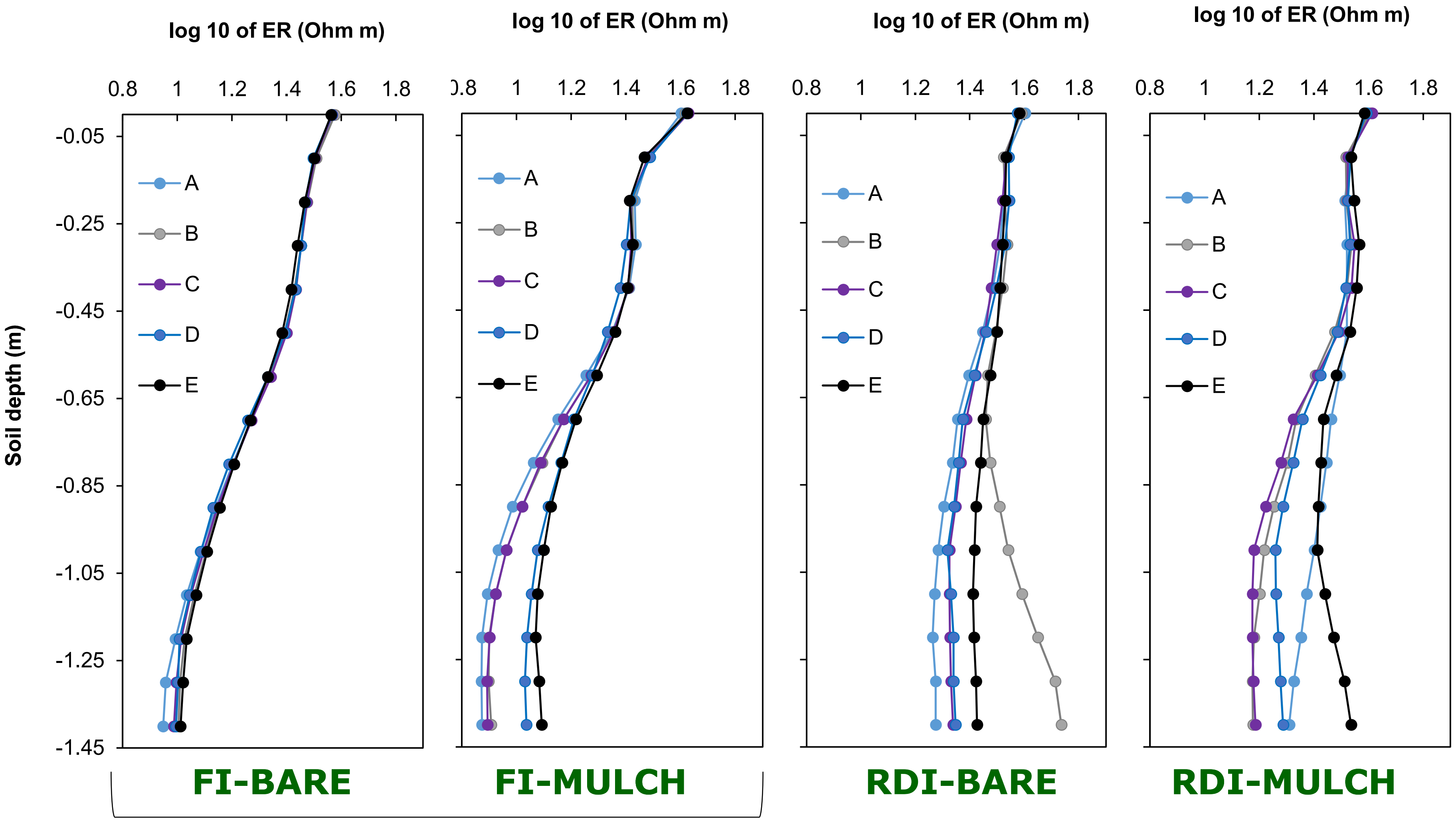
Temporal short-term ERT profiles: within the irrigation phase on July



More homogeneous ER conditions

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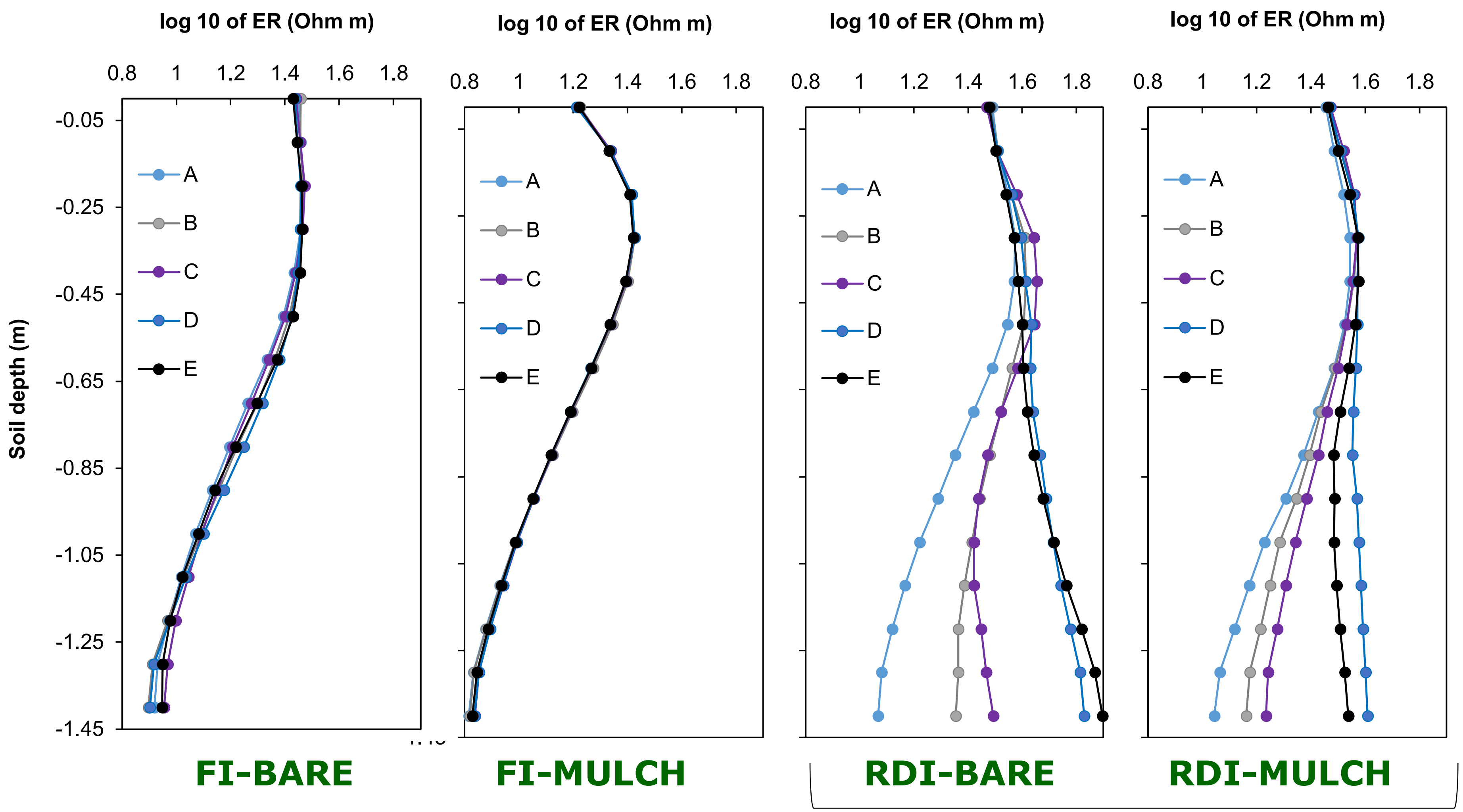
Temporal short-term ERT profiles: within the irrigation phase on September



Higher ER anomalies

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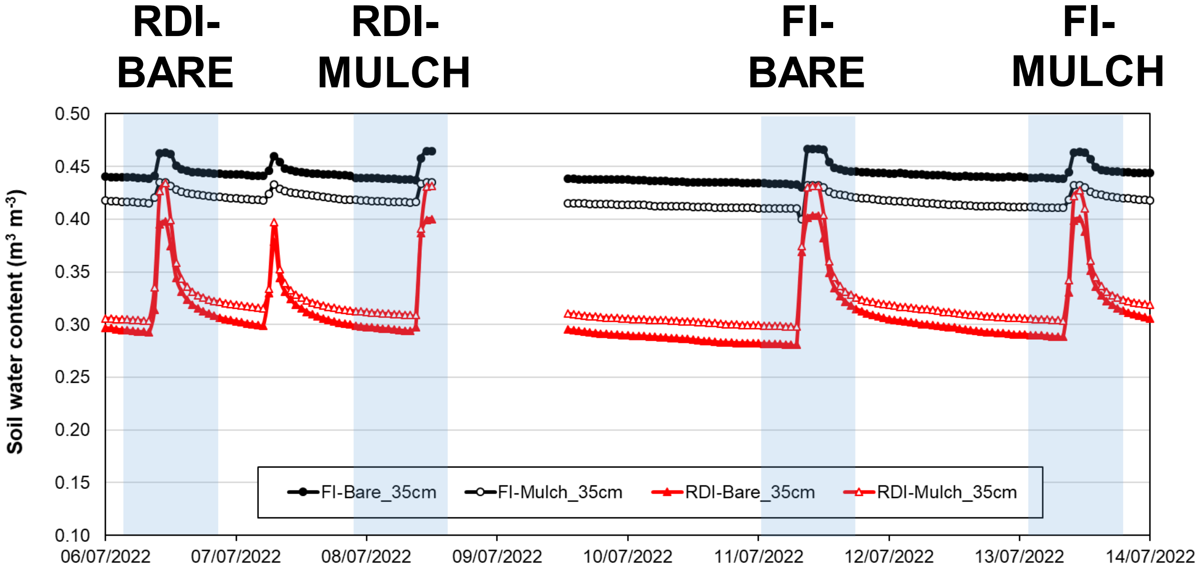
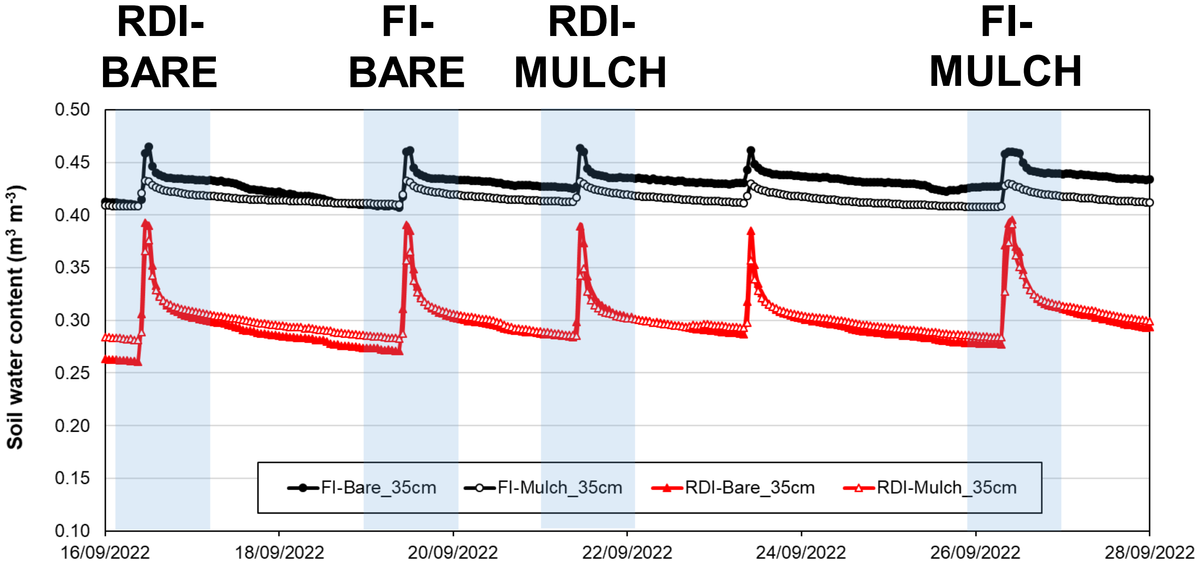
Temporal SWC evolution during ERT surveys



July



September

- At 30 cm depth, the SWC varied in a narrow range of values showing a largely constant trend both on July and September for all treatments;
- The RDI treatments were more affected by the irrigation inputs as can be seen from the marked SWC fluctuations occurring in correspondence of the irrigation events (clear blue rectangles).

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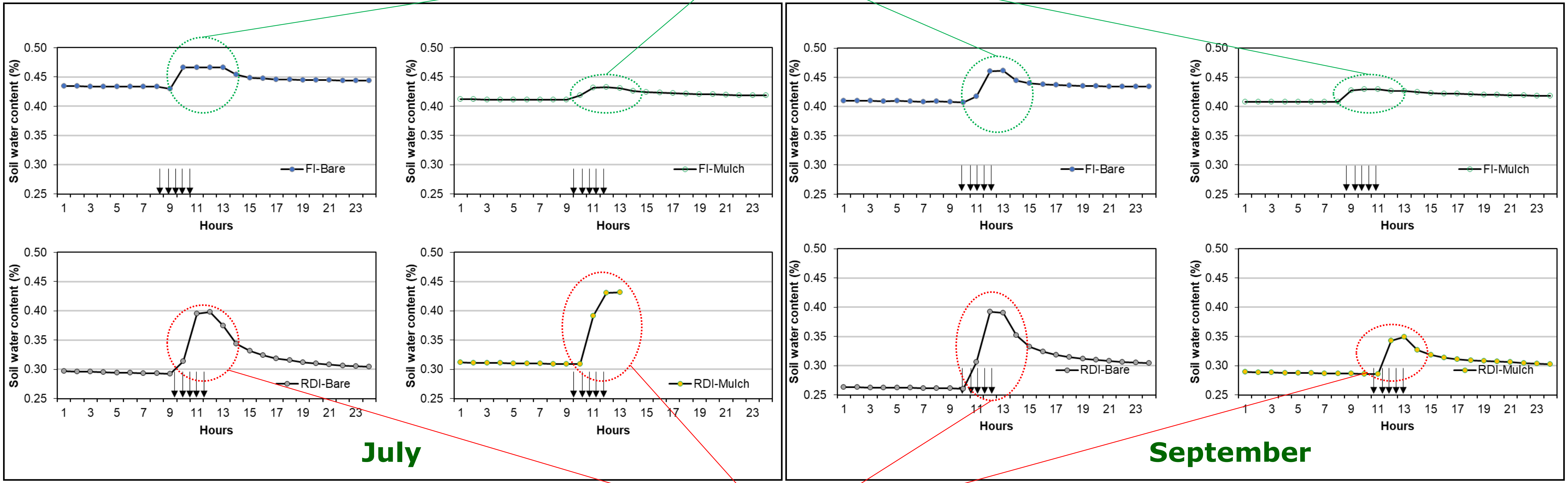
SWC during the short-term ERT monitoring during the irrigation phase

More stable SWC under FI, especially under mulched soils

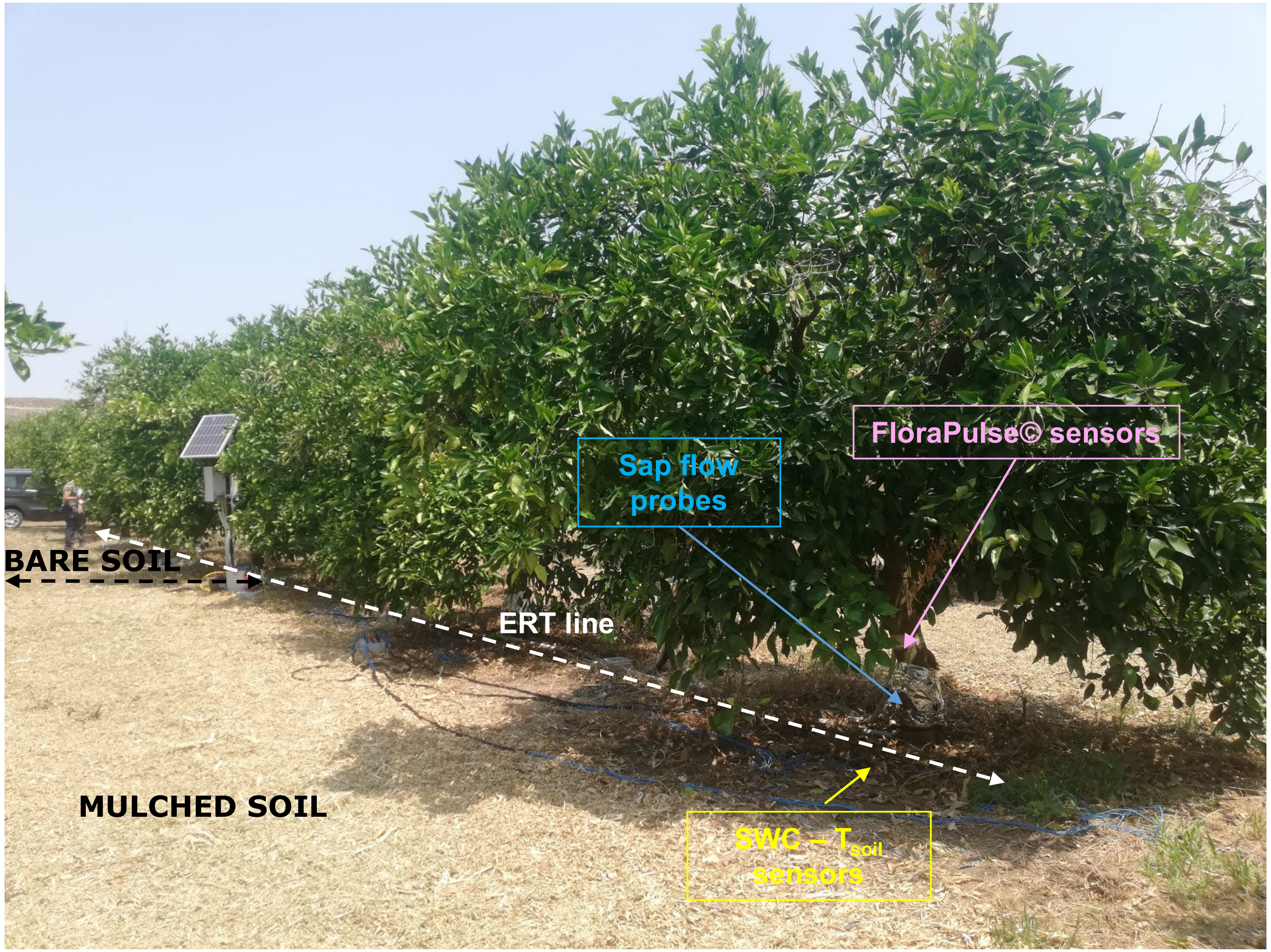


Higher SWC variability under RDI

Limited SWC fluctuations under mulched soils!

Sicilian case study 2 – Sustainable agricultural practices

Aims and materials and methods

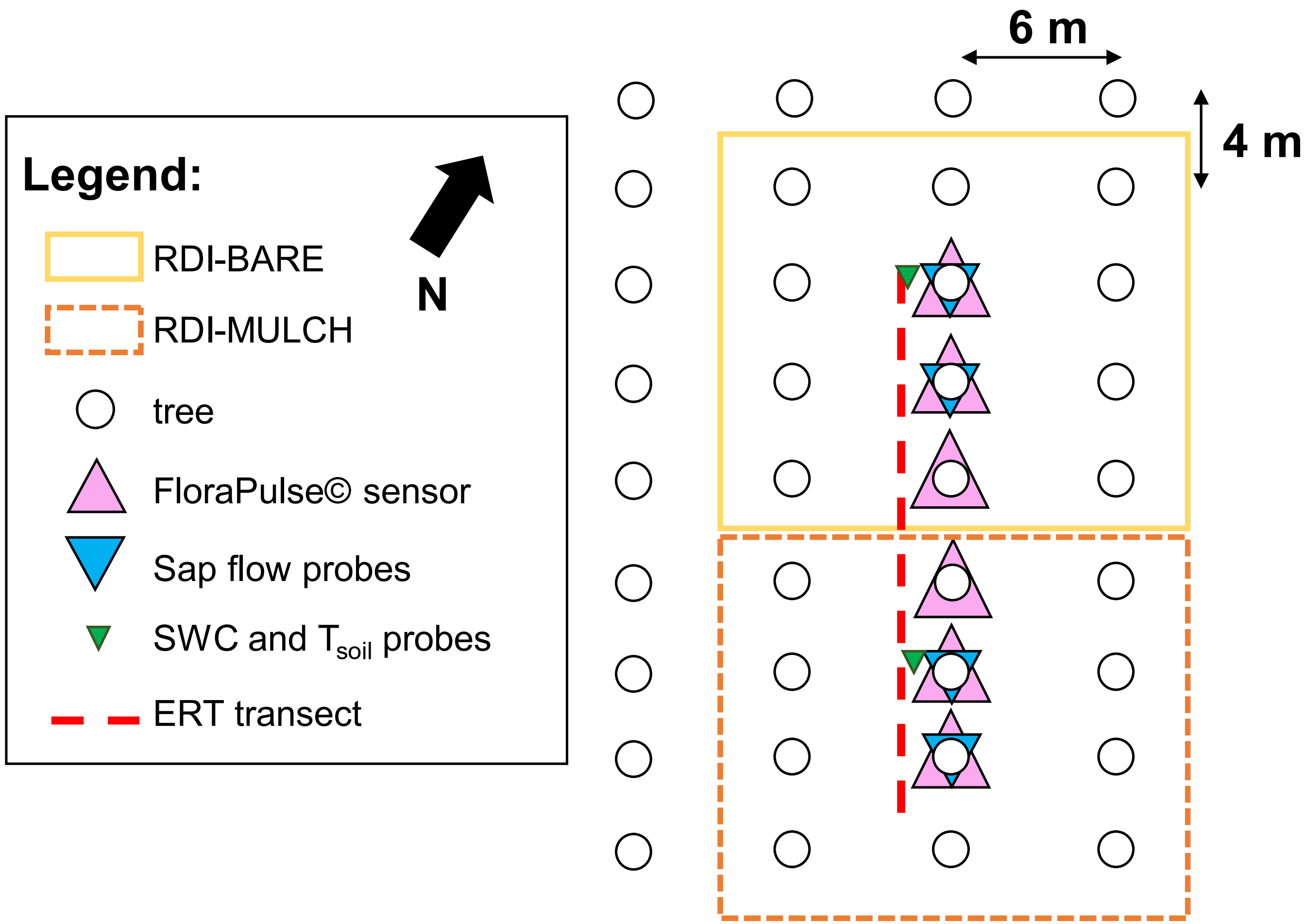


- 2 treatments supplied by RDI strategies both under bare and/or organic mulched soil conditions;

- To explore the soil-water-plant relationships by coupling the time-lapse ERT-based information with point-based measurements referring both to the soil and tree water status.

Sicilian case study 2 – Sustainable agricultural practices

Overview of the ERT layout and sensors locations at treatment level



FloraPulse© sensor

Sap flow probes

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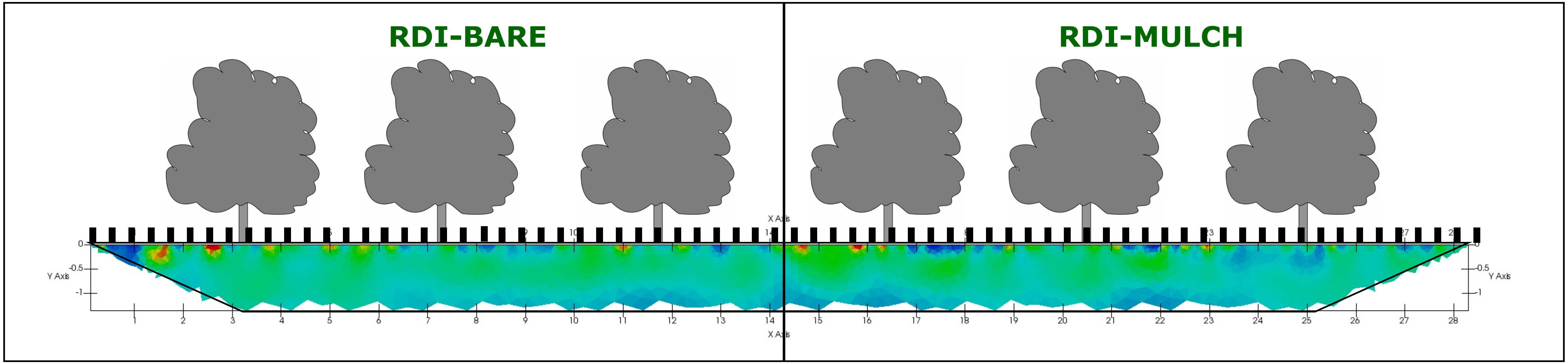
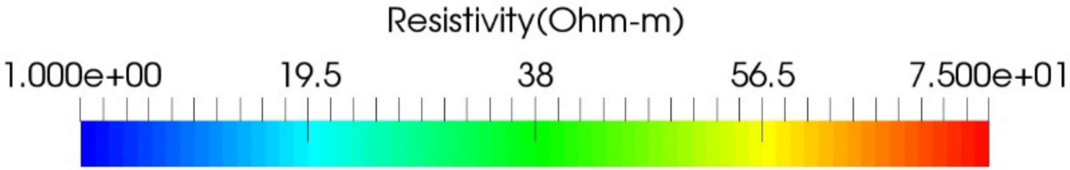
Absolute ERT inversions: August, 2023 (before irrigation)



no irrigation condition	time 00
during the irrigation phase	time 01 … time n



Homogenoeus ER patterns along the transect

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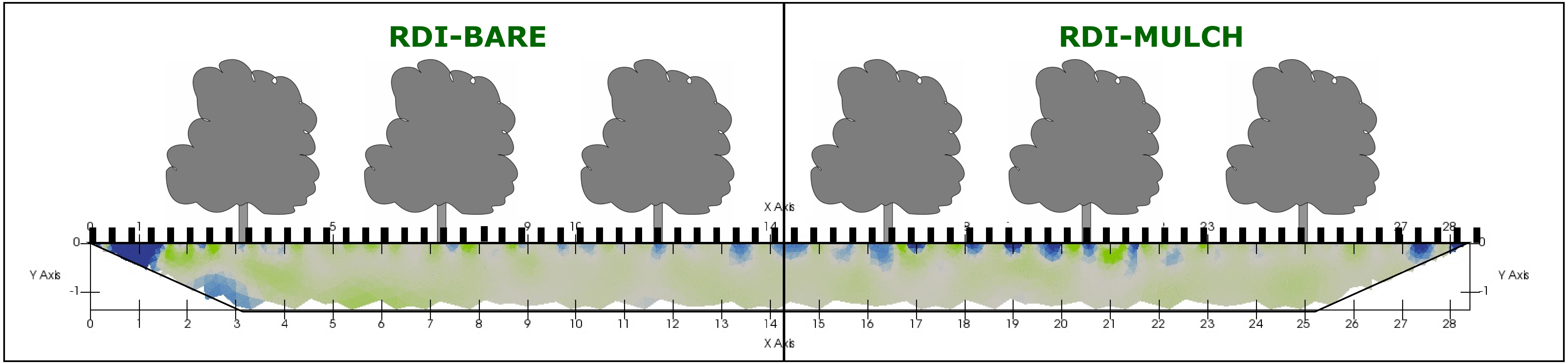
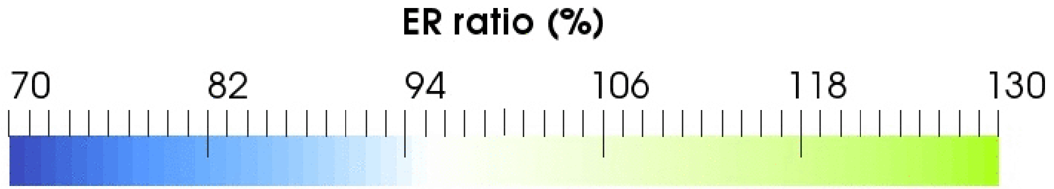
Temporal short-term ERT profiles: within the irrigation phase



no irrigation condition — time 00

during the irrigation phase — time 01 … time n



Simultaneous soil wetting and drying patterns

Sicilian case study 2 – Sustainable agricultural practices

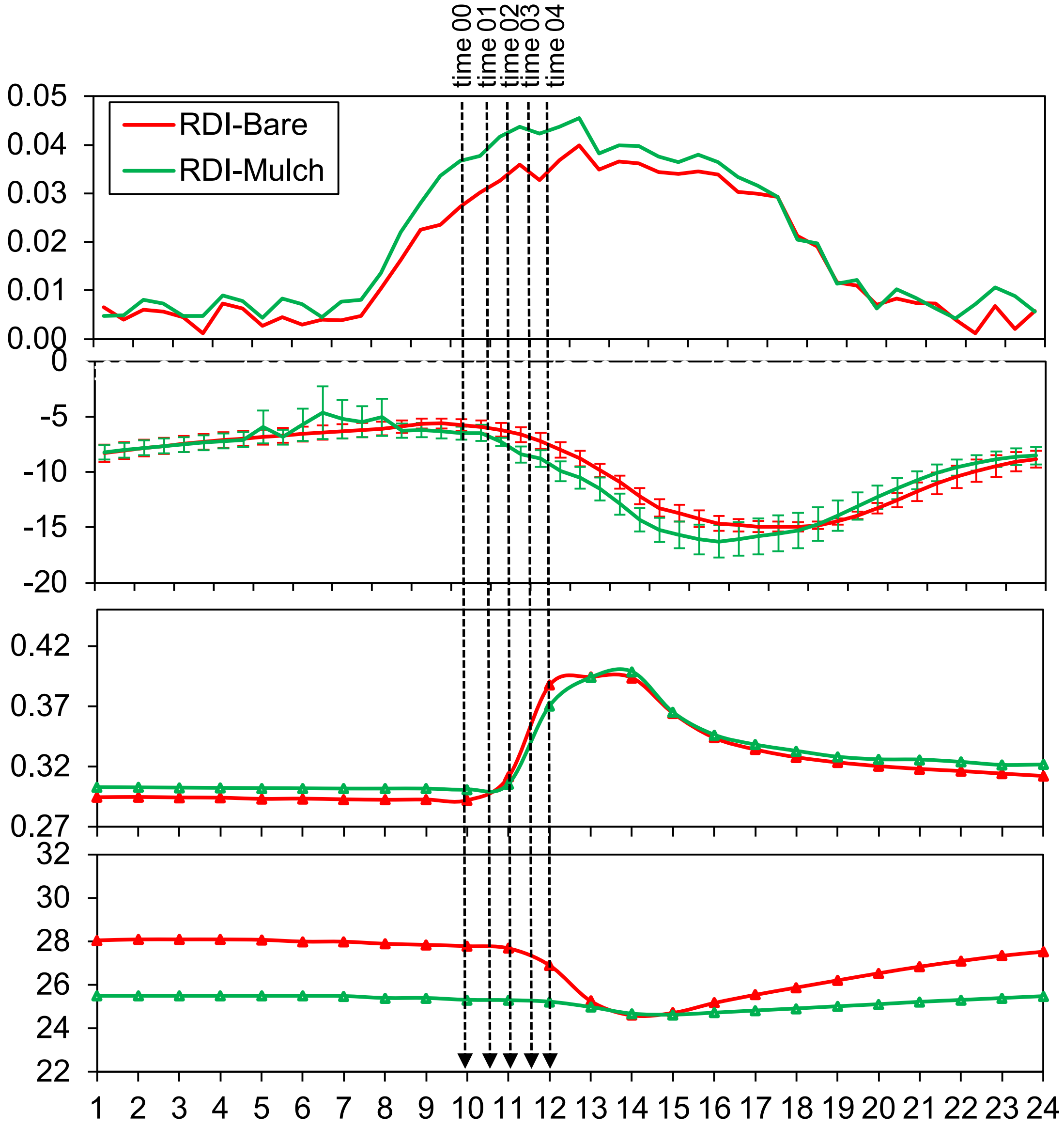
Crop and soil water status during ERT surveys

Transpiration fluxes (mm/d)

Trunk water potential (bar)

Soil water content (m^3 m^{-3})

Soil temperature (C°)

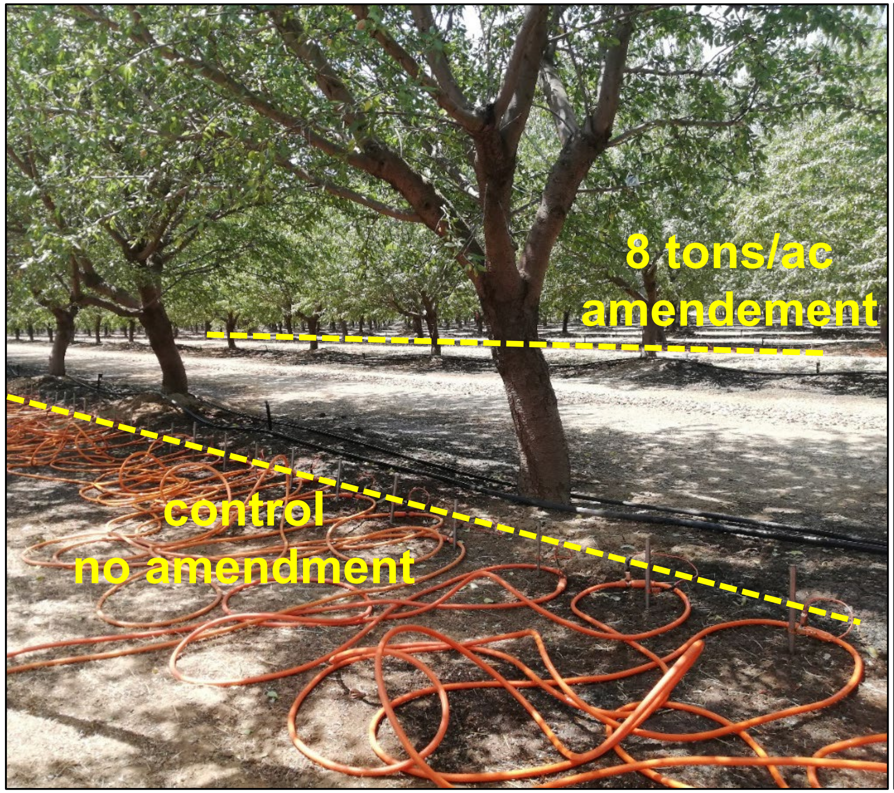


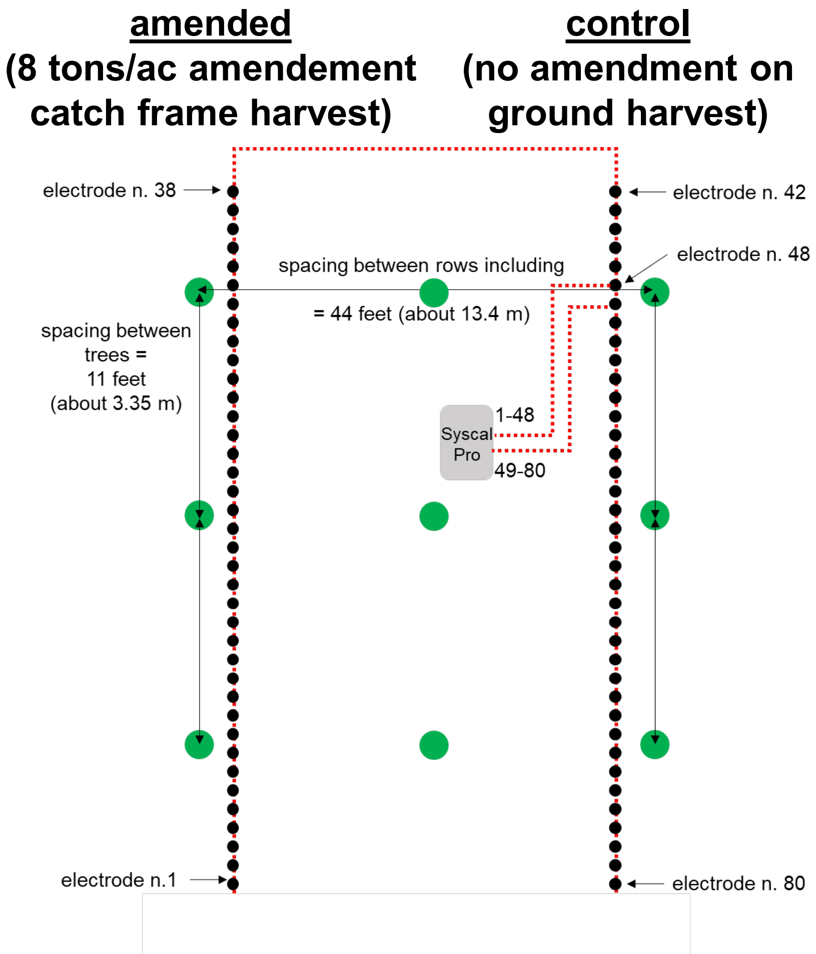
Mulched soils recover faster their status both in terms of trunk water potential and soil water status

Californian case study 1 – Sustainable soil management

Aims and materials and methods

Time-lapse ERT surveys were conducted **in an almond orchard characterized** by 2 treatments **(i.e., a control and an amended treatment, respectively)**. A total n. of 9 ERT dataset were acquired before (n. 1) and during (n. 8) an irrigation event at both treatments





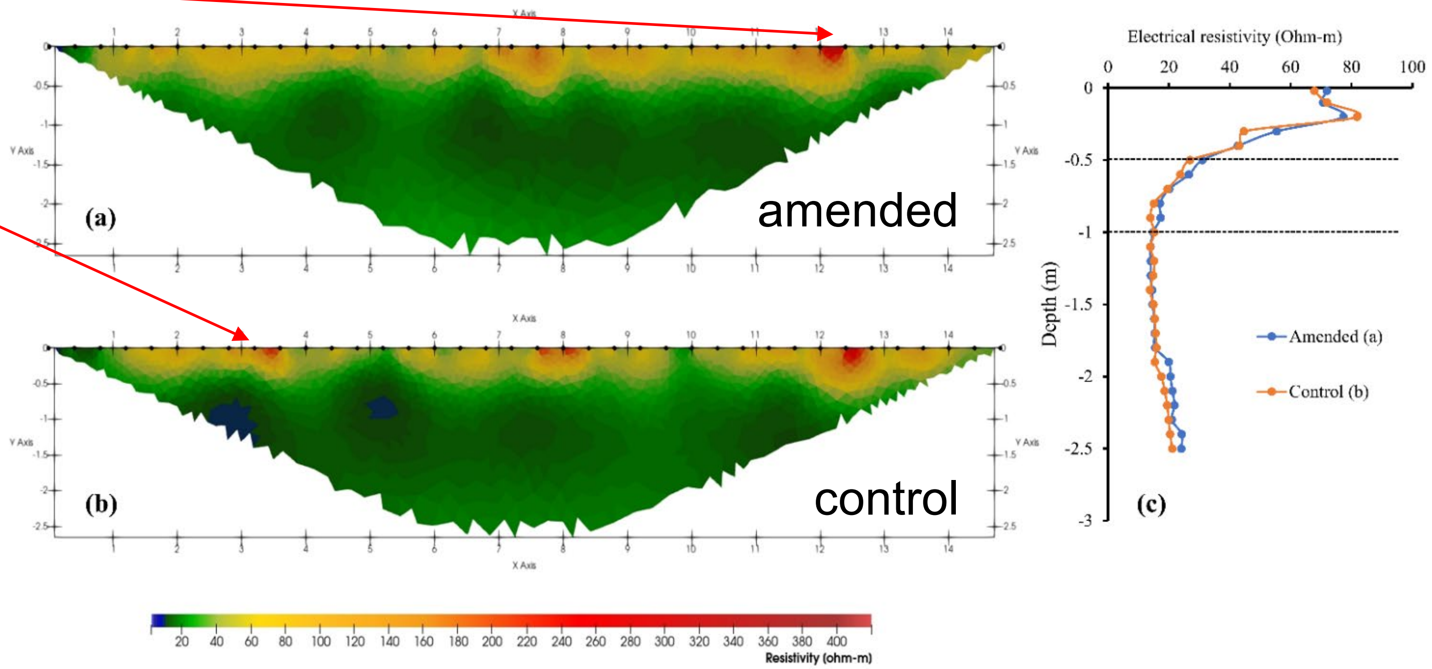
Kisekka et al., (under review)

Westwind site in California (USA)

Californian case study 1 – Sustainable soil management

Absolute ERT inversions: bare *versus* amended soils (initial conditions)

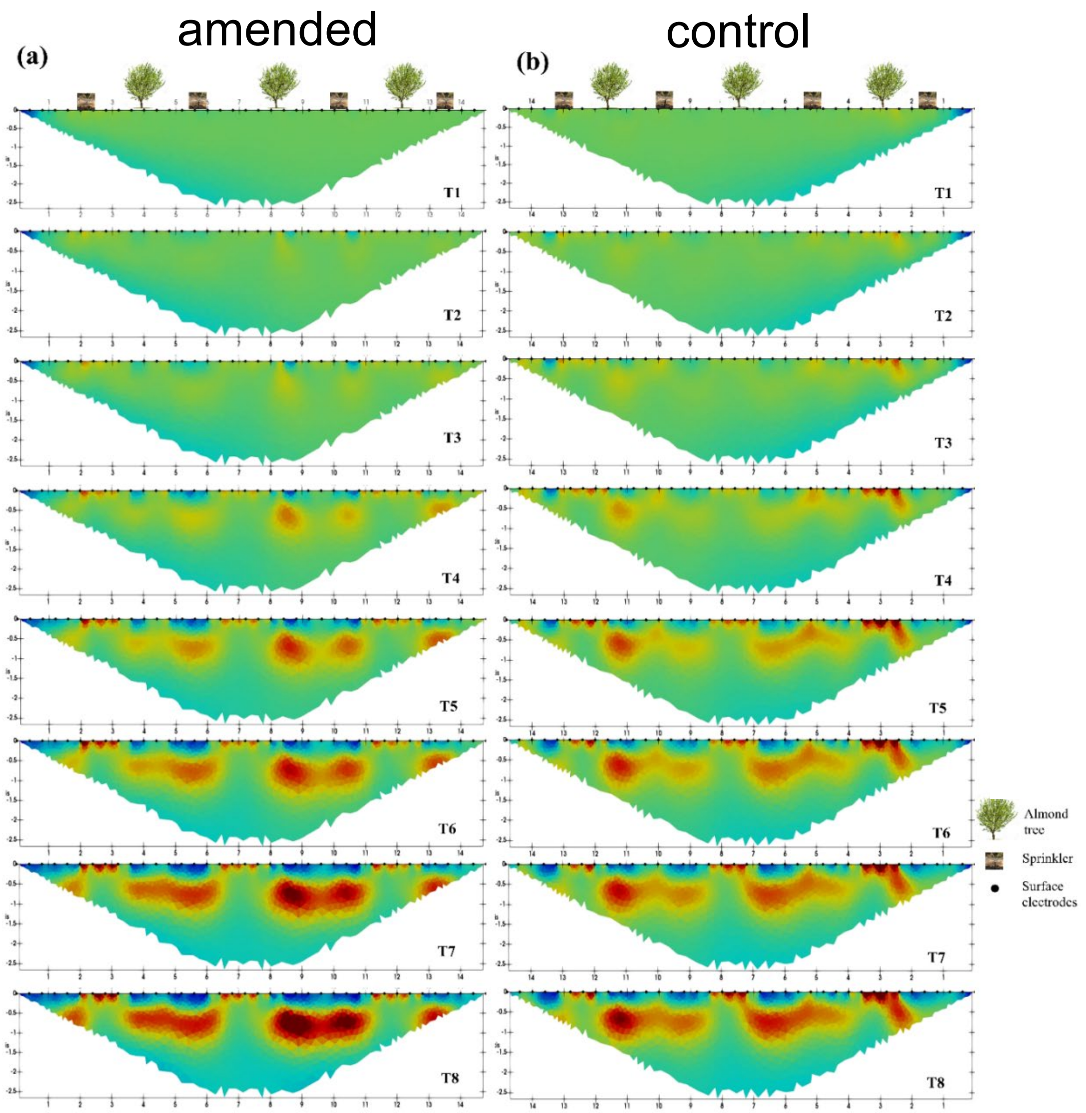
Greater ER values at some soil surface locations



Kisekka et al., (under review)

Californian case study 1 – Sustainable soil management

Temporal short-term ERT profiles: within the irrigation phase

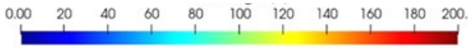


Soil drying patterns ranging to 0.5 to 1 m of the soil depht

Greater wetting fronts at the amended treatment

Greater infiltration capacity and less soil evaporation?

ER ratio (%)



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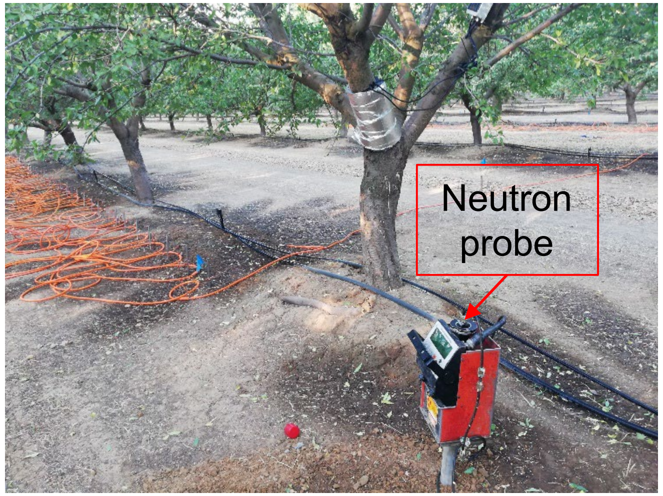
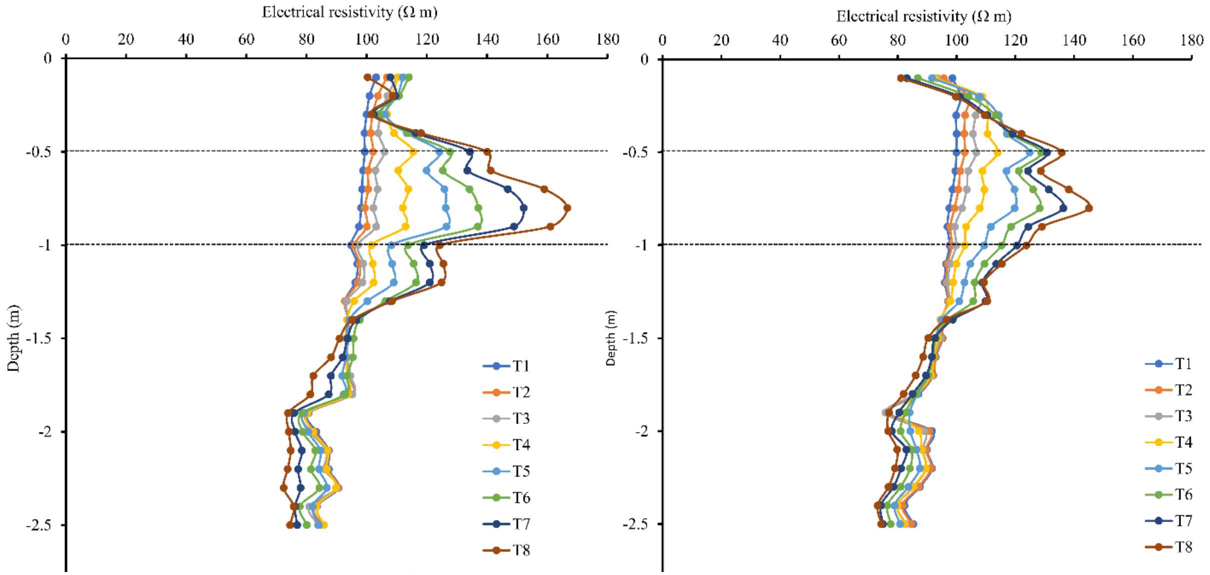
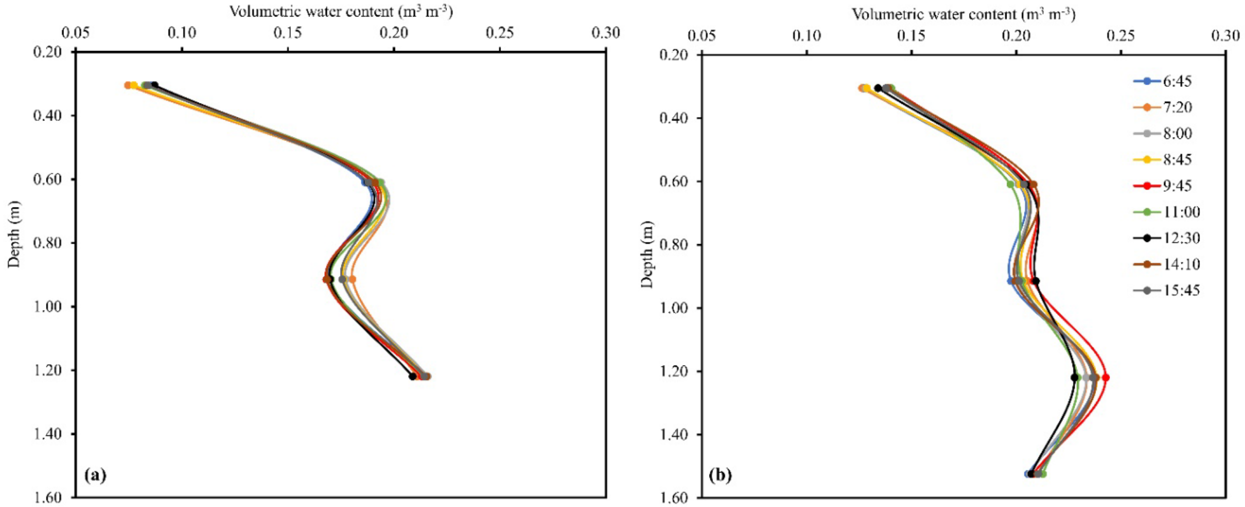


amended control





Greater variation in ER under the amended treatment

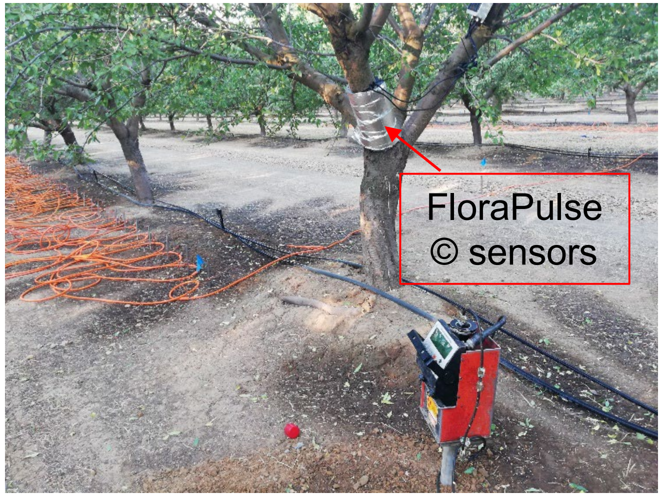
Organic amendments improves the water infiltration into the soil and enhances the RWU of the almond trees?

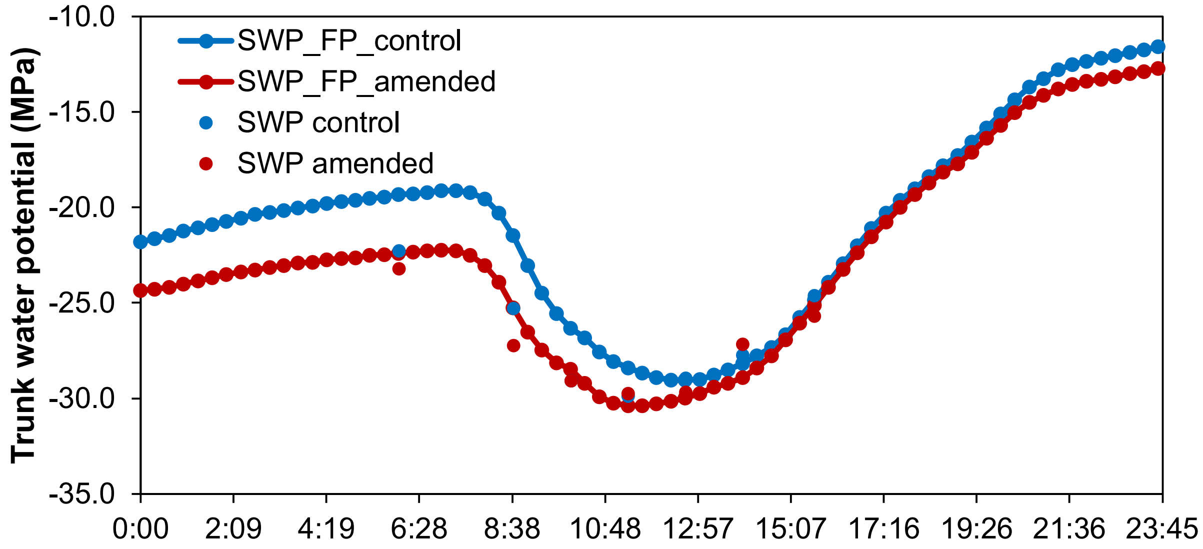
No significant changes were observed in SWC monitored using a neutron probe near the ERT transects

Kisekka et al., (under review)

Californian case study 1 – Sustainable soil management

Tree water status during ERT surveys





More negative trunk water potential values at the amended treatments

Higher RWU?

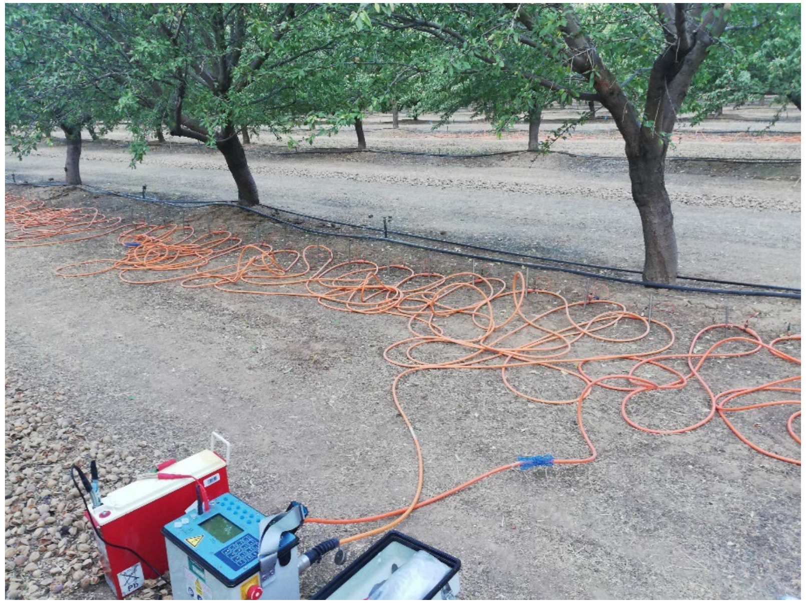
Kisekka et al., (under review)

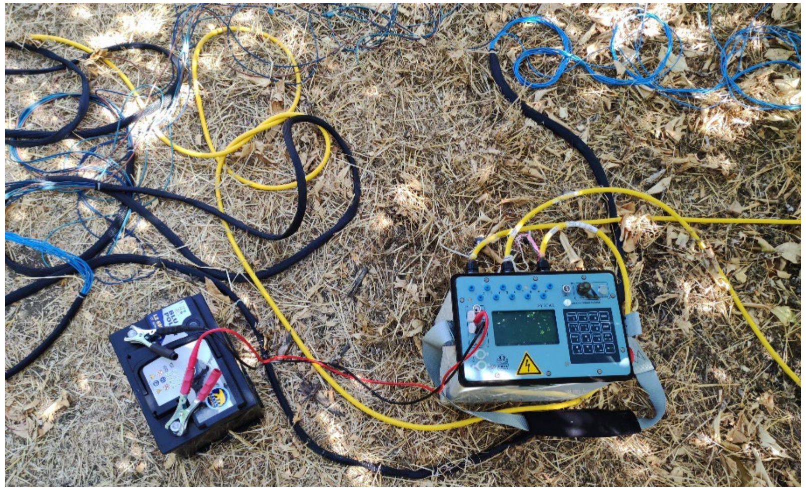
Conclusive remarks:

- The use of geo-electrical imaging offers great tools for inferring the main environmental key parameters, such as the temporal soil water features in the root-zone of tree crops;

- The combination of time-lapse ERT monitoring together with soil and tree water status measurements helps to gain a better understanding of the soil hydrologic processes (i.e., the infiltration and RWU processes) for a more precise management of the orchards;

- These understanding are pivotal for determining the environmental effects related to the adoption of precision agriculture criteria.





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