Induced uneven spatial distribution of agrochemicals due to preferential flow in water repellent soils and its remediation by surfactant

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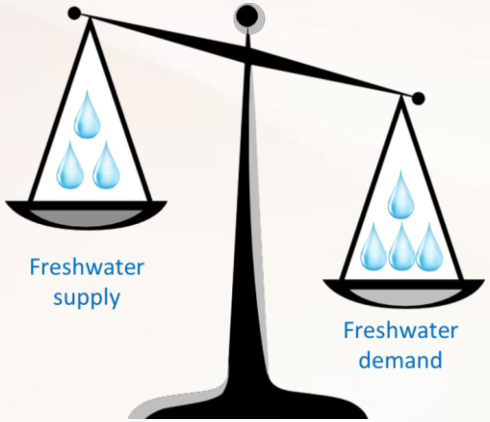
Introduction

By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions. – UNWWDR, 2015



WASTEWATER

The untapped resource

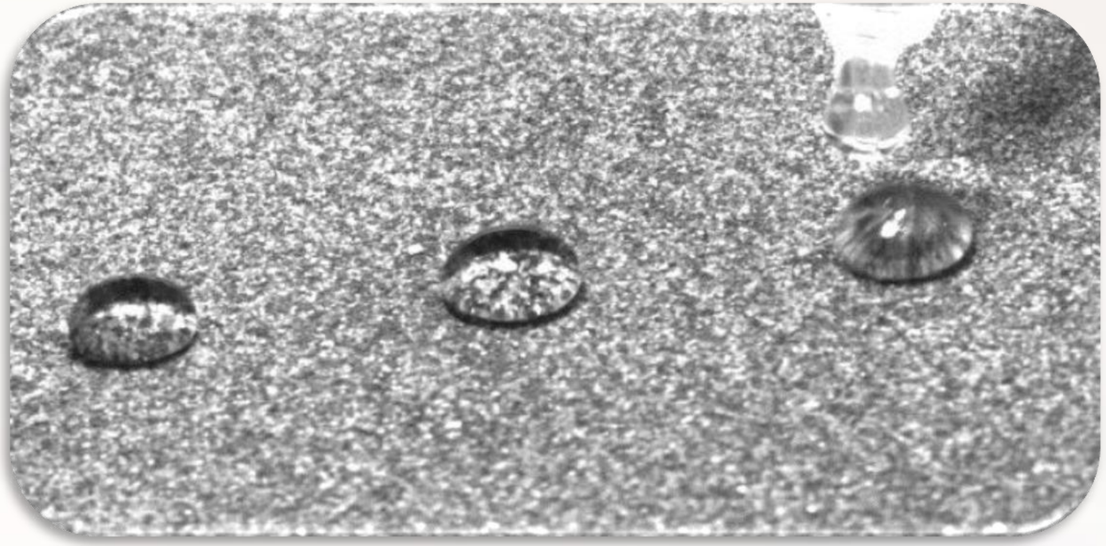
UNWWDR, 2017

The use of treated wastewater for irrigation as a means of freshwater conservation has been proposed and encouraged. However, it comes with some drawbacks one of which is soil water repellency (SWR)

Soil water repellency

Problems in SWR

- Reduced infiltration
- Increased surface runoff
- Soil erosion
- Development of preferential flow pathways, consequently, resulting in uneven distribution of moisture and agrochemicals



Water droplets staying on top of a water repellent soil

Stable vs Unstable flow due to water quality induced SWR

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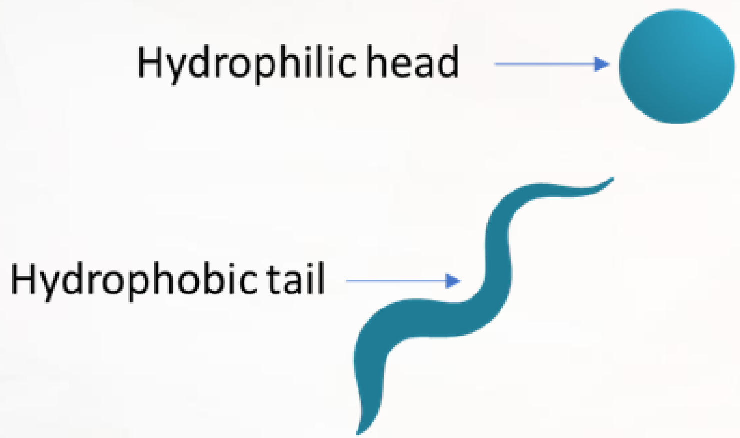
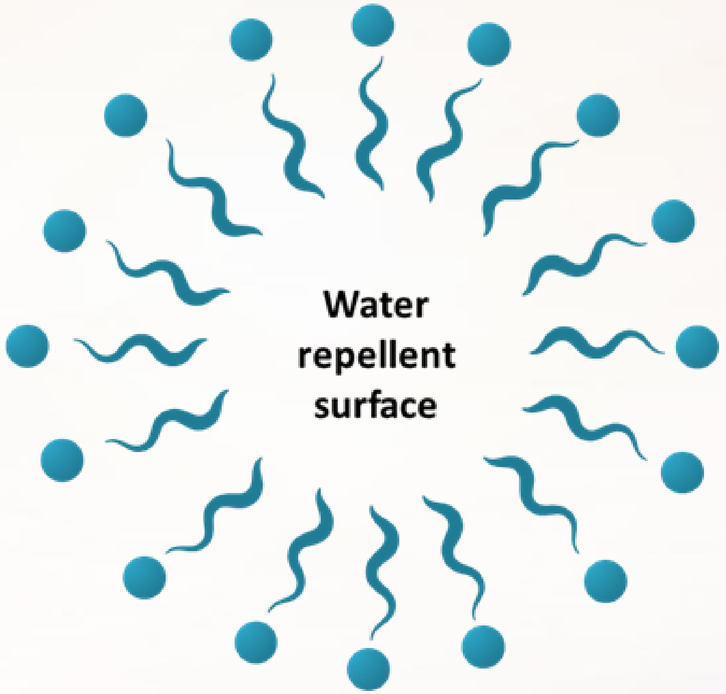
Surfactants

Surfactants (wetting agents) have been used for different purposes in agriculture, inter alia to reduce the negative effects of soil water repellency



Surfactant molecule



Surfactant on a water repellent surface

The objective

To study the use of nonionic surfactant to ameliorate soils rendered water repellent by long-term irrigation with TWW. This study investigates how surfactant application to a commercial orchard soil reduces the uneven spatial distribution of water and agrochemicals and the leaching beyond the root zone.

Experimental setup

- Six plots that were rendered water repellent to irrigation using treated wastewater (TWW) were selected.
- Surfactant #20 was sprayed onto the soil surface as a remediation for the soil water repellency.
- Three surfactant concentrations (0, 5 & 10 g/L) were sprayed onto the soil surface every 14 days during the irrigation season.
- Frequent ERT scans were taken before, during and after irrigation.
- Moisture content and chemical distribution were determined for 150 disturbed soil samples taken along a transect parallel to the tree rows.

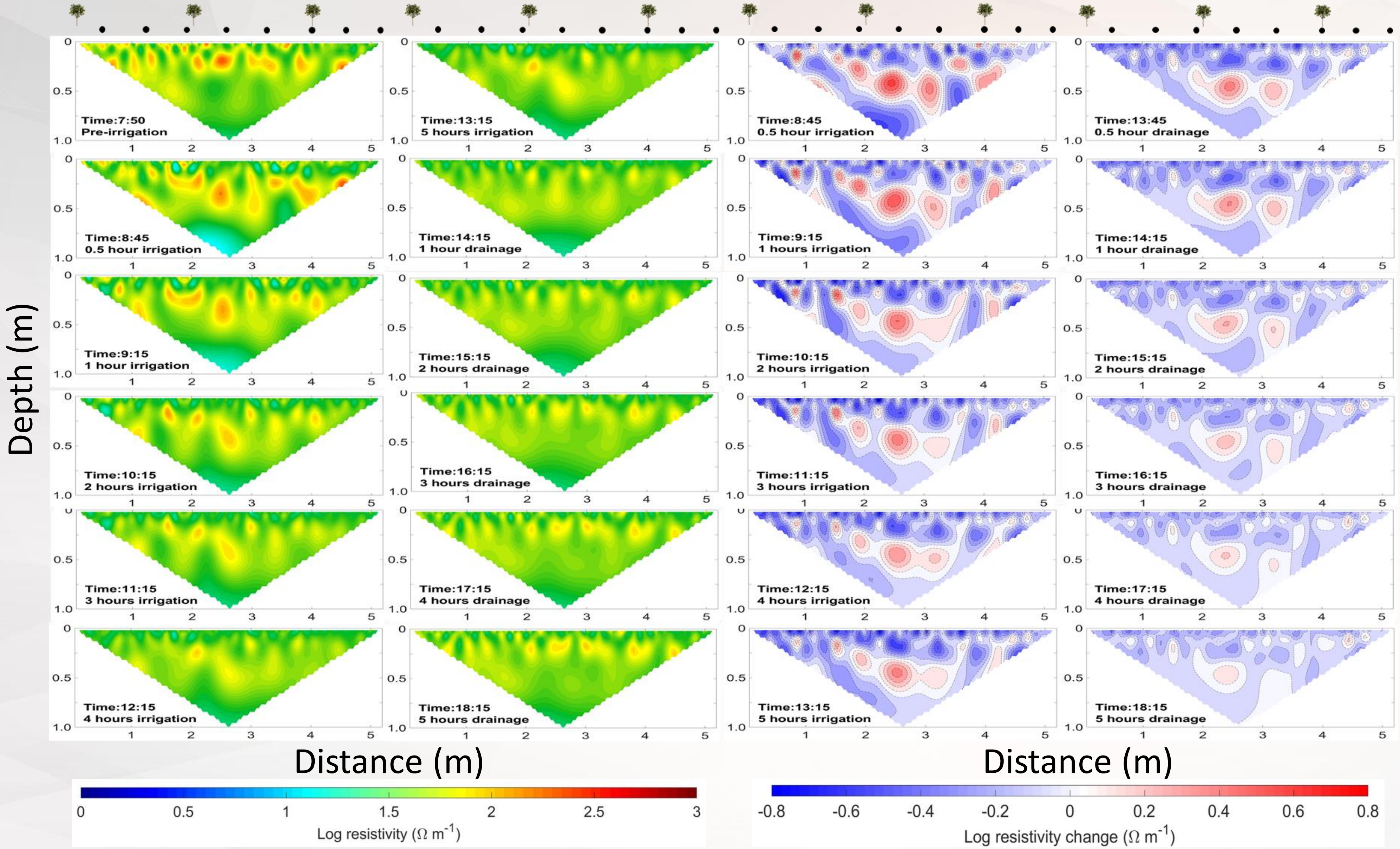
The ERT system

Soil sampling

Gravimetric MC measurement

Soil Laboratory

Temporal Changes in ER of 0 g/L surfactant treated soil



Results

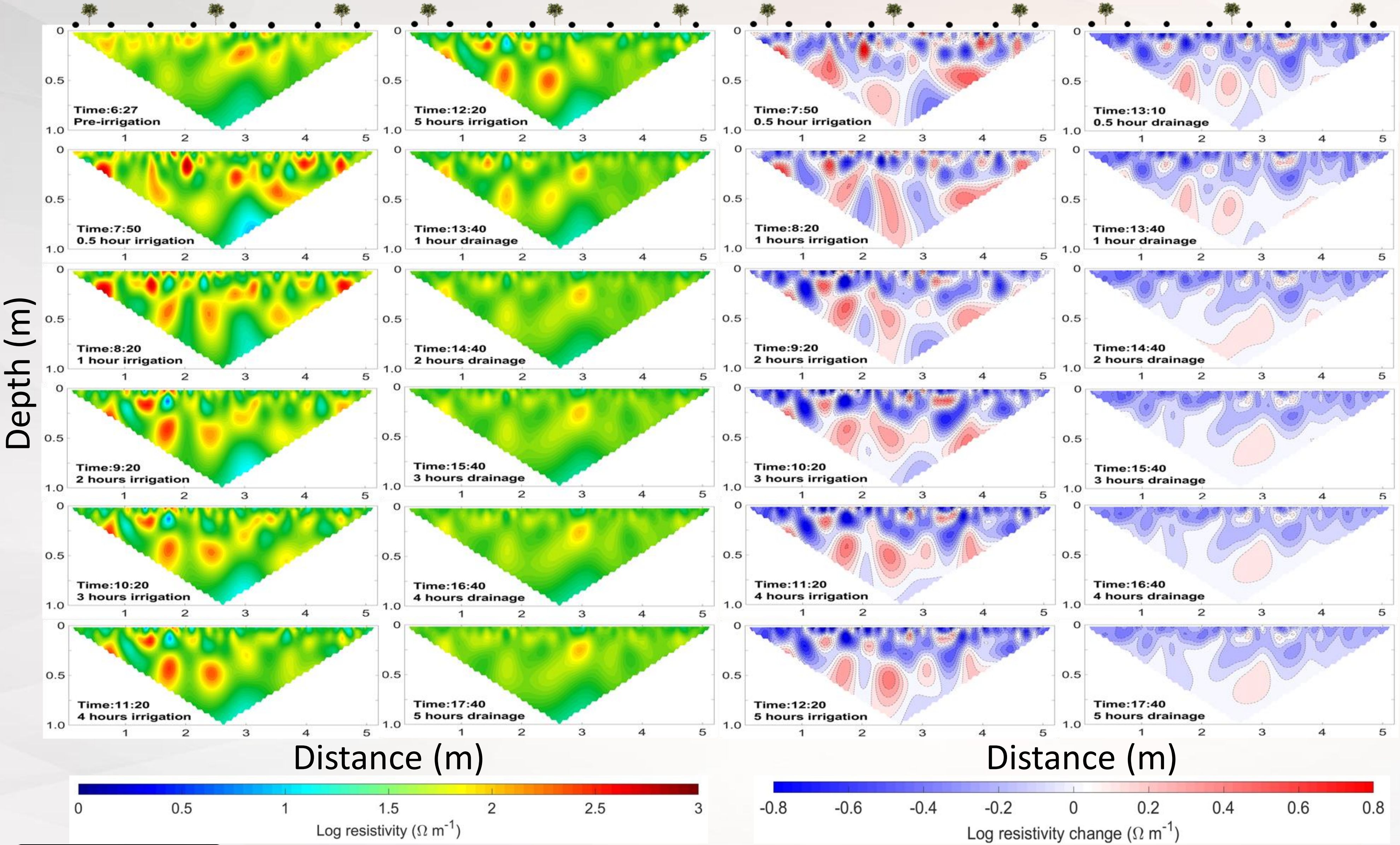
a. Unstable flow can be seen within the profile

b. Many dry spots by-passed during wetting

c. Water is leached downwards through the preferential flow during wetting and redistribution

The change in resistivity is the deviation of subsequent scans from the initial soil scan prior to irrigation. Trees and black dots represent represents trees and drippers positions, respectively.

Temporal Changes in ER of 5 g/L surfactant treated soil



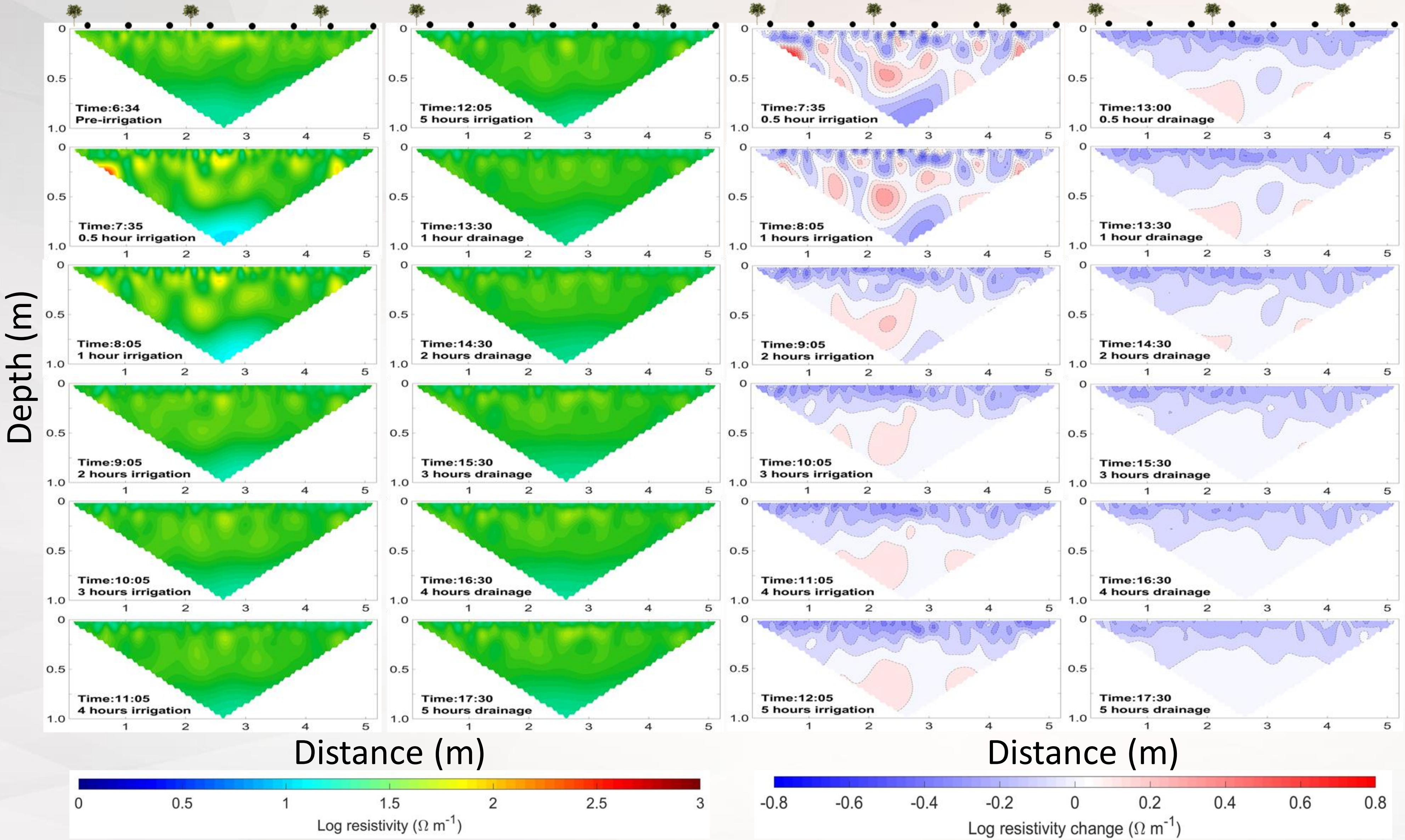
Results

a. Unstable wetting flow within the soil profile can be still seen.

b. Less water is leached downwards during wetting, whereas no obvious preferential pathways are observed during redistribution.

The change in resistivity is the deviation of subsequent scans from the initial soil scan prior to irrigation. Trees and black dots represent represents trees and drippers positions, respectively.

Temporal Changes in ER of 10 g/L surfactant #20 treated soil



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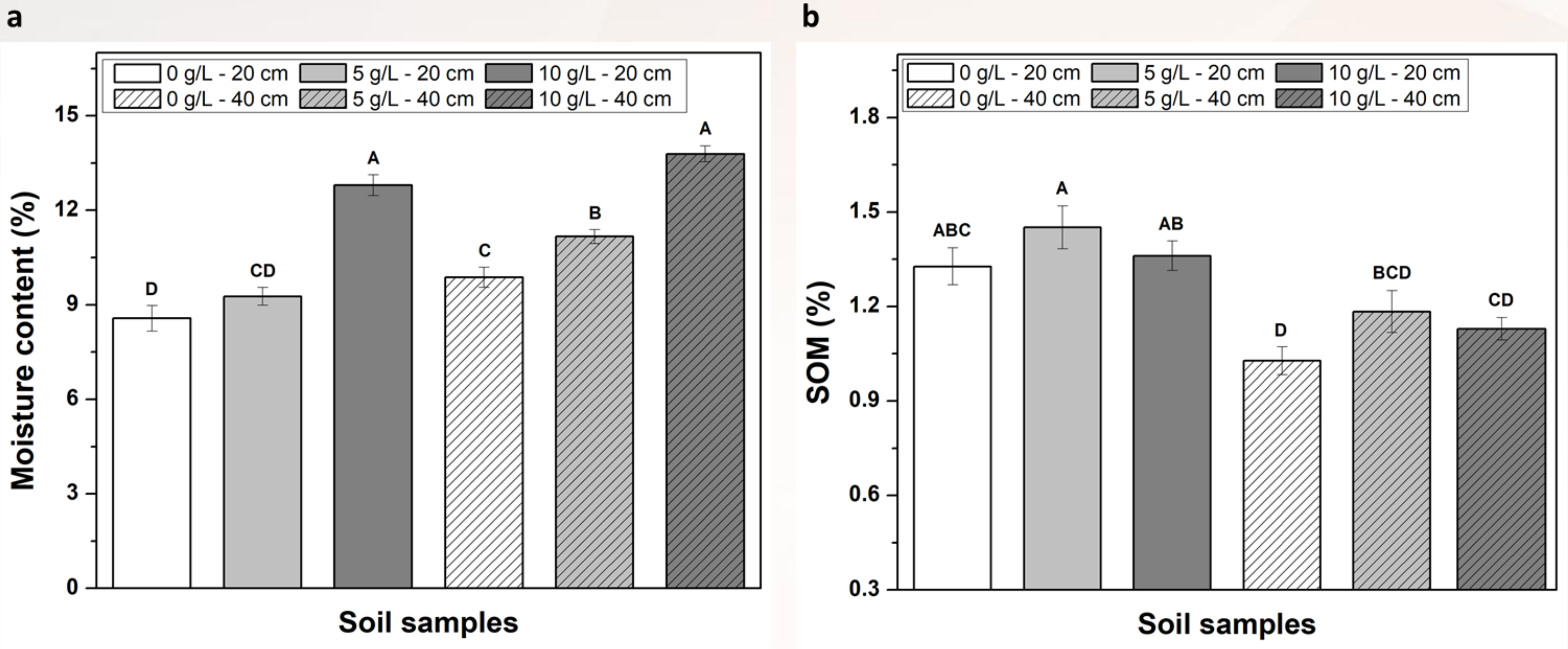
Results

a. Flow in the soil profile turned stable.

b. No leaching of water takes place during the wetting and redistribution stages.

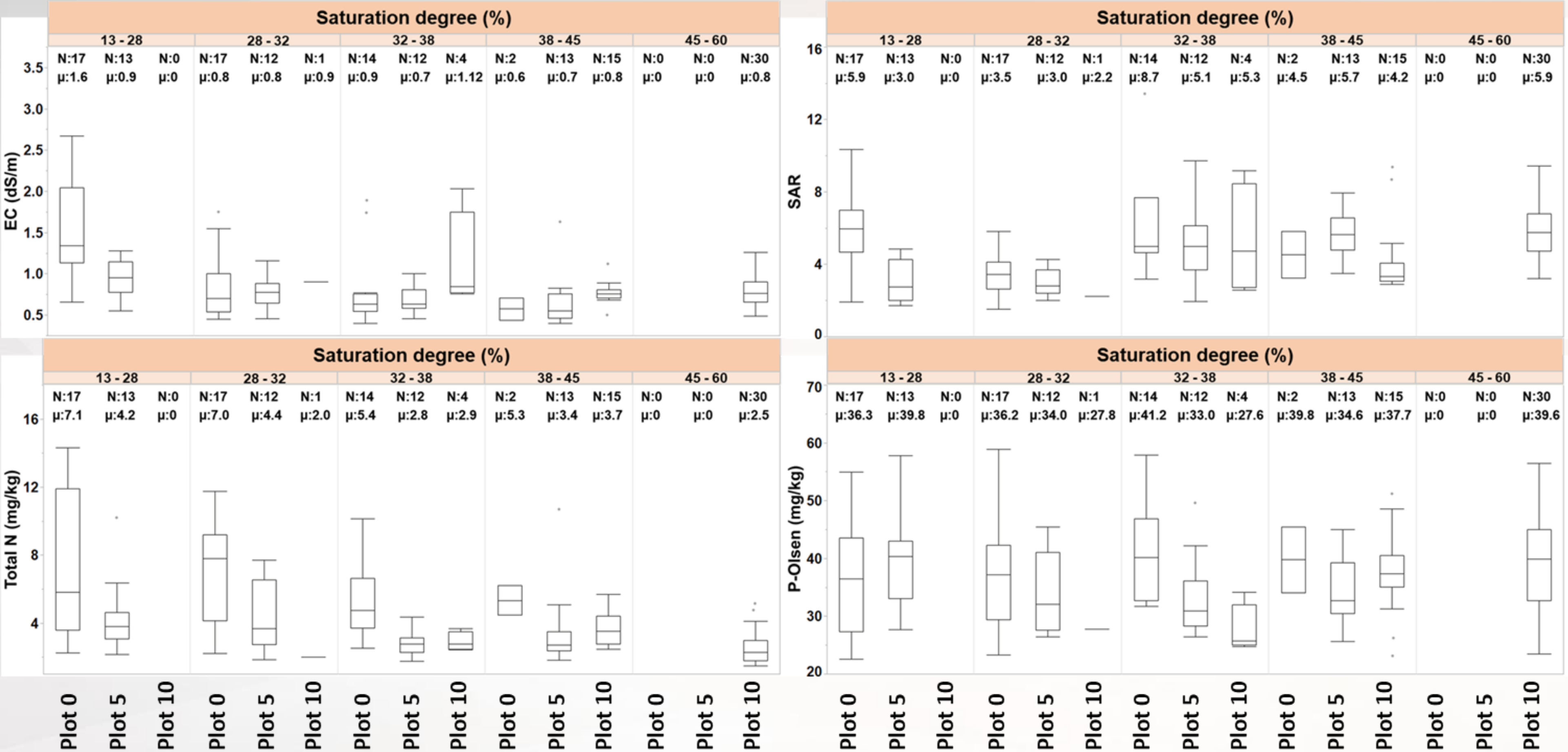
The change in resistivity is the deviation of subsequent scans from the initial soil scan prior to irrigation. Trees and black dots represent represents trees and drippers positions, respectively.

Surfactant treatment increases soil water content in the soil surface layer



Average soil moisture content (a) and organic matter content (b) of plots treated with different concentrations of surfactants #20 (n = 25, ±SEM). Different letters represent significant difference using Tukey HSD test (0.05)

Soil Chemical distribution of EC, SAR, N and P according to saturation following surfactant application



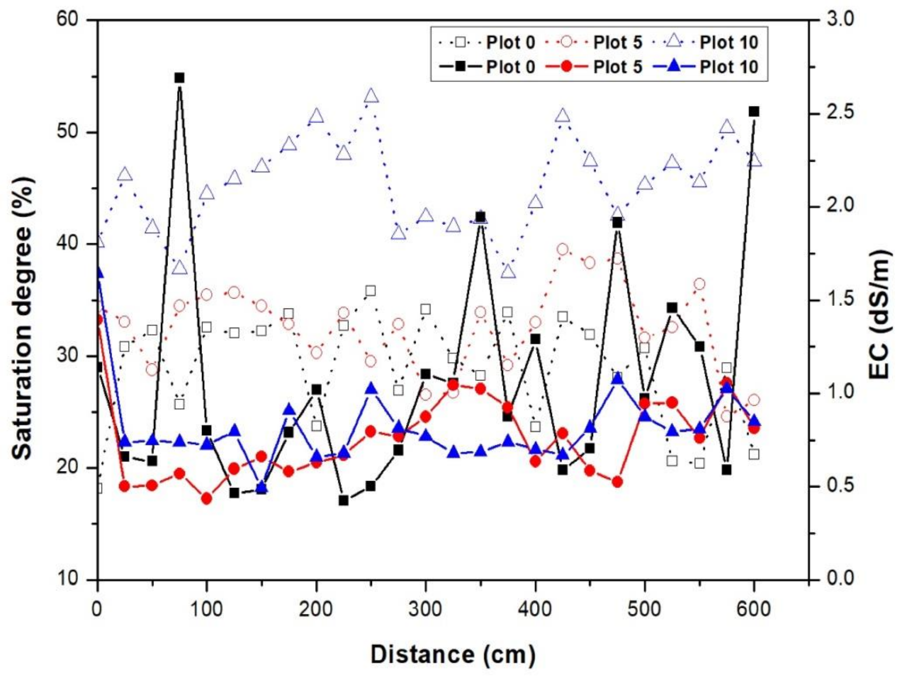
Distribution of EC, SAR, N and P according to saturation degree in 0, 5 and 10 g/L surfactant #20 treated plots. The data include soil samples that were collected from the 0–40 cm depths. The number of samples (N) and mean value falling into each category is given at the top of box plot.

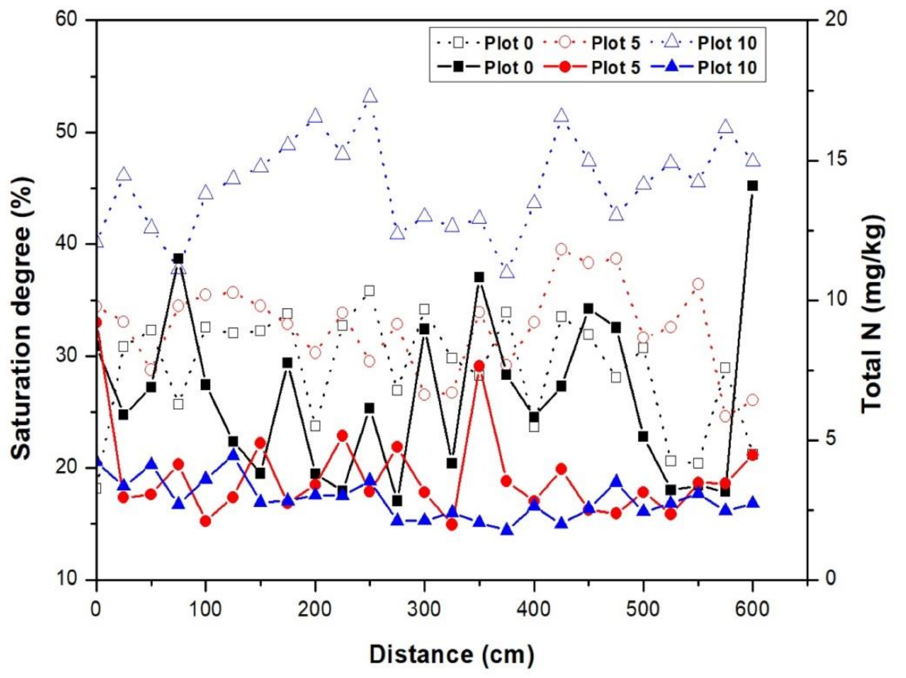
Results

a. In the 0 g/L treated soil higher chemical concentrations occurred at the very low moisture content and lower concentrations at the higher moisture contents. More even chemical distributions were obtained in the surfactant-treated soil.

b. Total N concentration is lower in the surfactant-treated soil, probably owing to higher uptake by the trees.

Saturation degree, EC, and N and distribution along a transect





Mean values for Saturation degree (dotted lines), EC and Total N (solid lines, respectively) along the transect at 25 cm interval for 0-40 cm depth during the fall sampling of 2019. Plot 0, 5 and 10 represent plots receiving 0, 5 and 10 g/L surfactant #20 treatments every 14 days. Same color represents the same plot

Results

a. Spatially uneven distribution of EC and N take place in the 0 g/L treated soil compared to the surfactant-treated soil in which the concentration distribution turned more uniform.

Summary and Conclusion

A. Irrigation with TWW induce the development of SWR thereby causing uneven distribution of moisture and chemicals in the soil.

B. Soil saturation degree distribution was monitored by ERT while chemical distribution by disturbed soil sampling.

C. Surfactant treatment of TWW irrigated soil reverted the problems of SWR, namely, leading to a more uniform wetting and chemical distribution.

D. Surfactant treatments resulted in a significant increase in soil moisture due to the remediation of preferential flow pathways, while it showed no effect on the fate of adsorbed nutrients.

E. Surfactant spraying on the soil surface used in this study intended to emulate soil mixing with surfactant rather than surfactant application via a drip system that was found non effective (Ogunmokun et al., 2020) . Further study is still needed to find a better practical way for surfactant application in commercial orchards.