The effect of treated wastewater irrigation on the spatial distribution of water and solutes in the root zone and their availability to the plants

Rony Wallach

The R.H. Smith Faculty of Agriculture, Food and Environment,

The Hebrew University of Jerusalem, Israel

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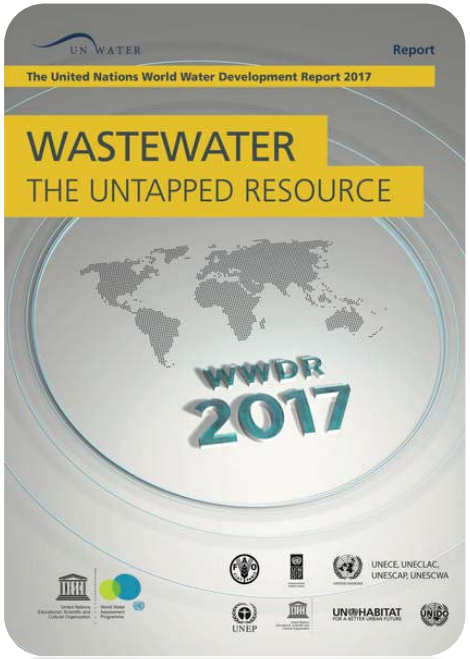
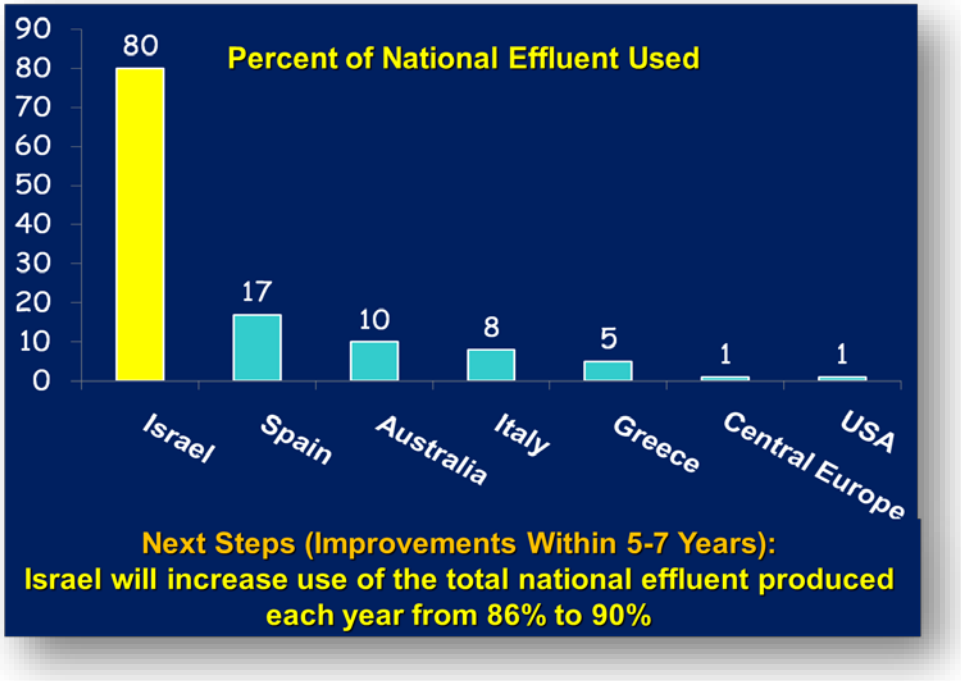
The use of treated wastewater (TWW) for Irrigation in Israel

Currently, ~50% of water used for agriculture is treated wastewater.

It will increase to 67% by 2050.



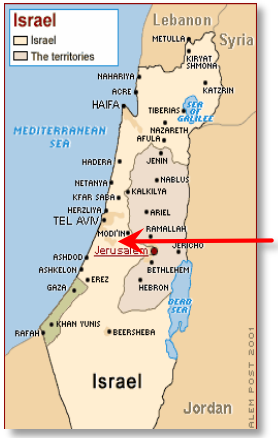


Today, most orchards in Israel are irrigated with TWW.

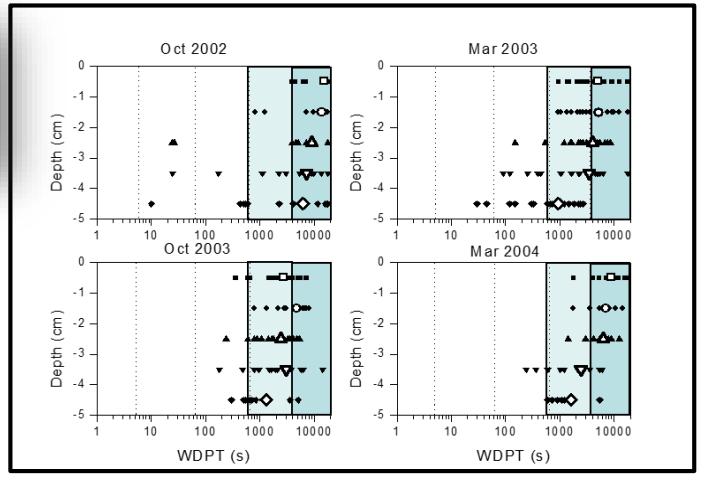
While the benefits of using TWW for irrigation are apparent, there is a growing number of findings claiming that prolonged TWW-irrigation has some negative effects on the soil and plant environment:

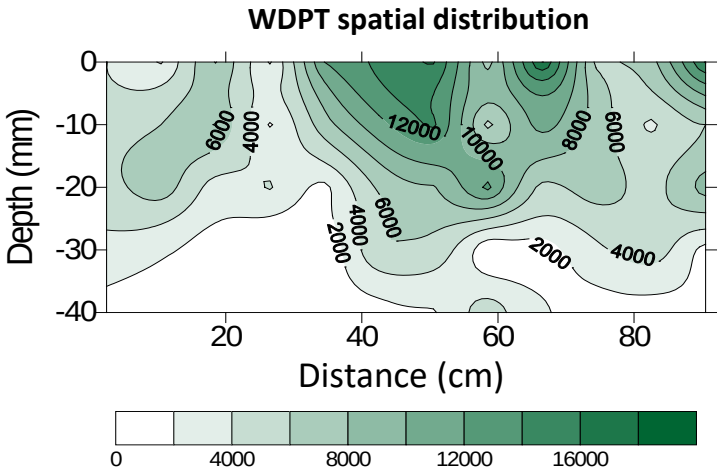
- TWW irrigated soils have higher dissolved organic matter (DOM), suspended solids, sodium adsorption ratio (SAR), and salinity compared to FW-irrigated soils.
- It was found that continuous use of TWW reduces of tree growth and yield.
- TWW affects various aspects of soil hydrology as well.

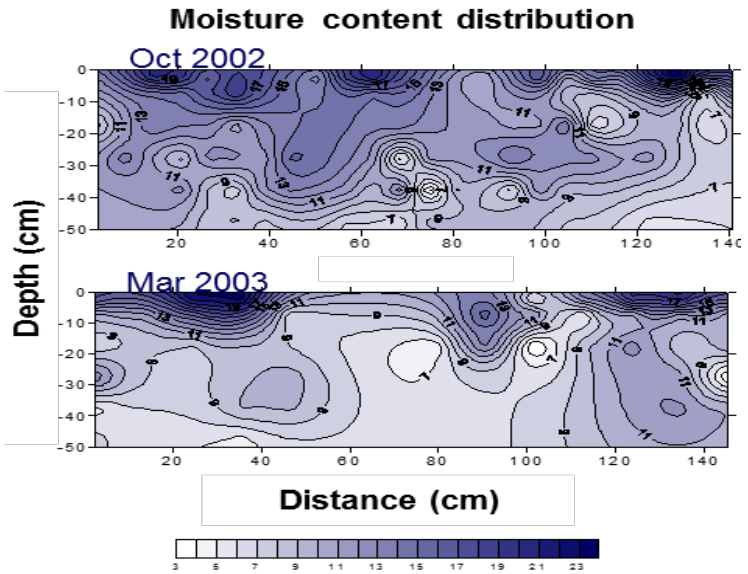
TWW irrigation renders the soil hydrophobic – first evidence



Safariya orchard, Israel



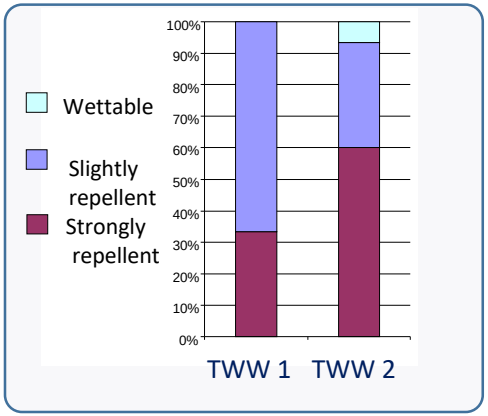




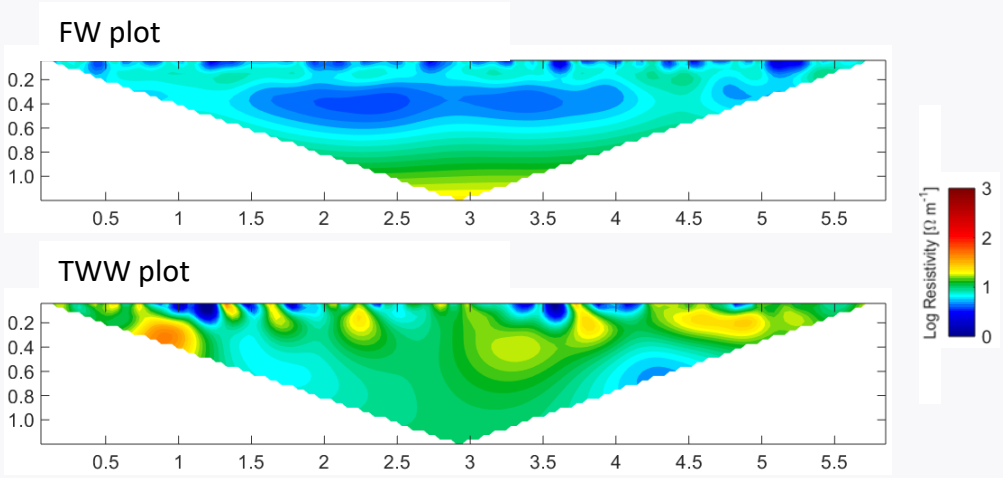
Wallach et al., *JEQ* 2005

TWW effect on soil water spatial distribution - (ERT) surveys in FW and TWW plots

TWW plots FW plot

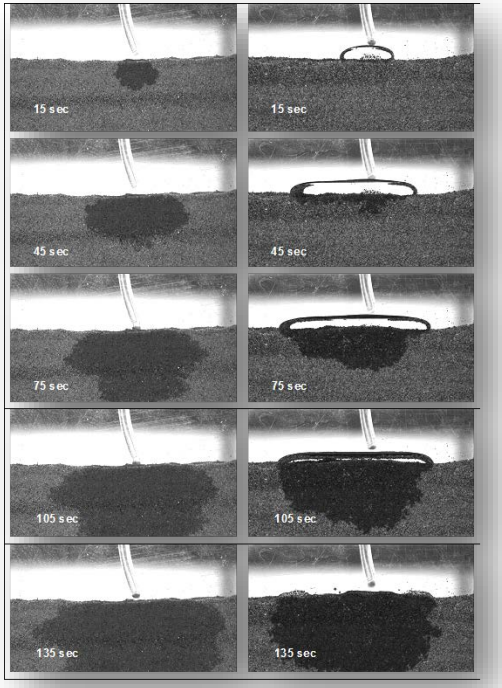


The ERT system



Brindt, *MSc Thesis*, 2012

Flow chamber (lab) study

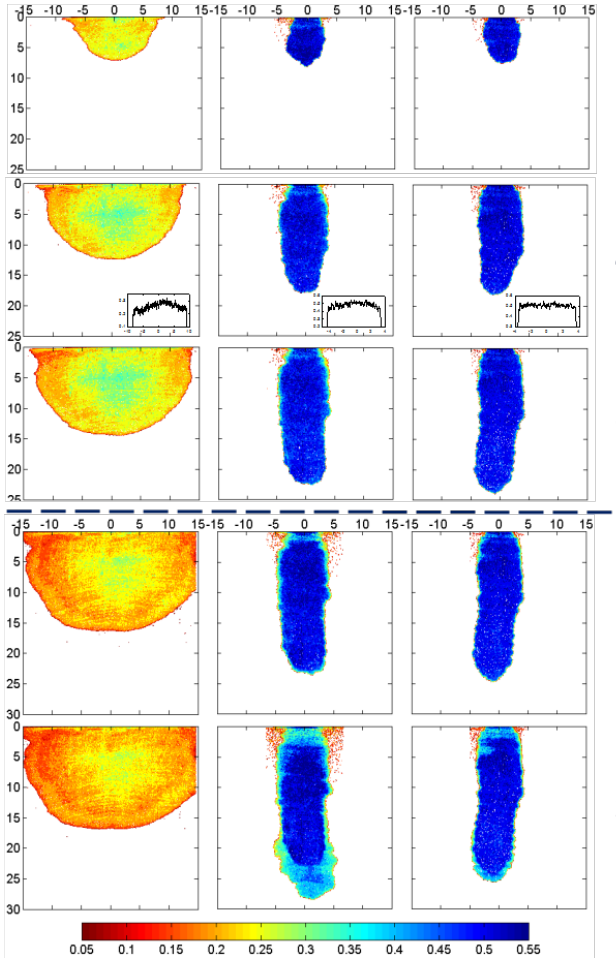


Wallach and Jortzik , *J. Hydrol* 2008

Soil water distribution from a point water source at the surface

Q = 1 ml min^{-1}

wettable | slightly repellent | strongly repellent



15 min Infiltration

45 min Infiltration

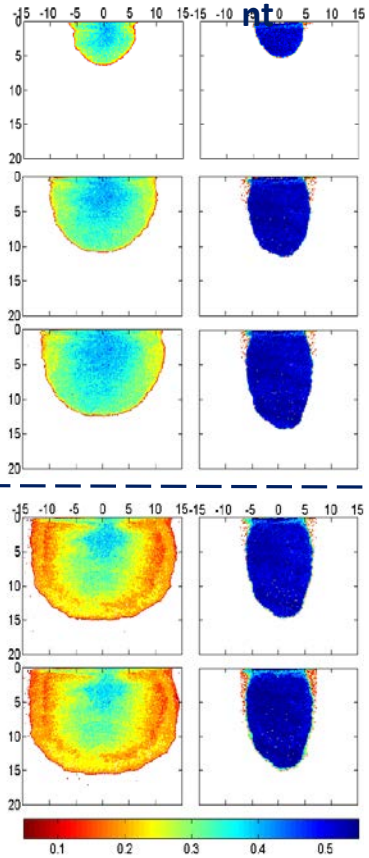
60 min Infiltration

1 h redistribution

2 and 10 h redistribution

Q = 5 ml min^{-1}

wettable | slightly repellent



3 min Infiltration

9 min Infiltration

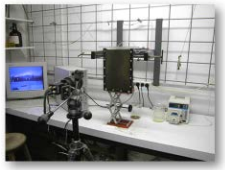
12 min Infiltration

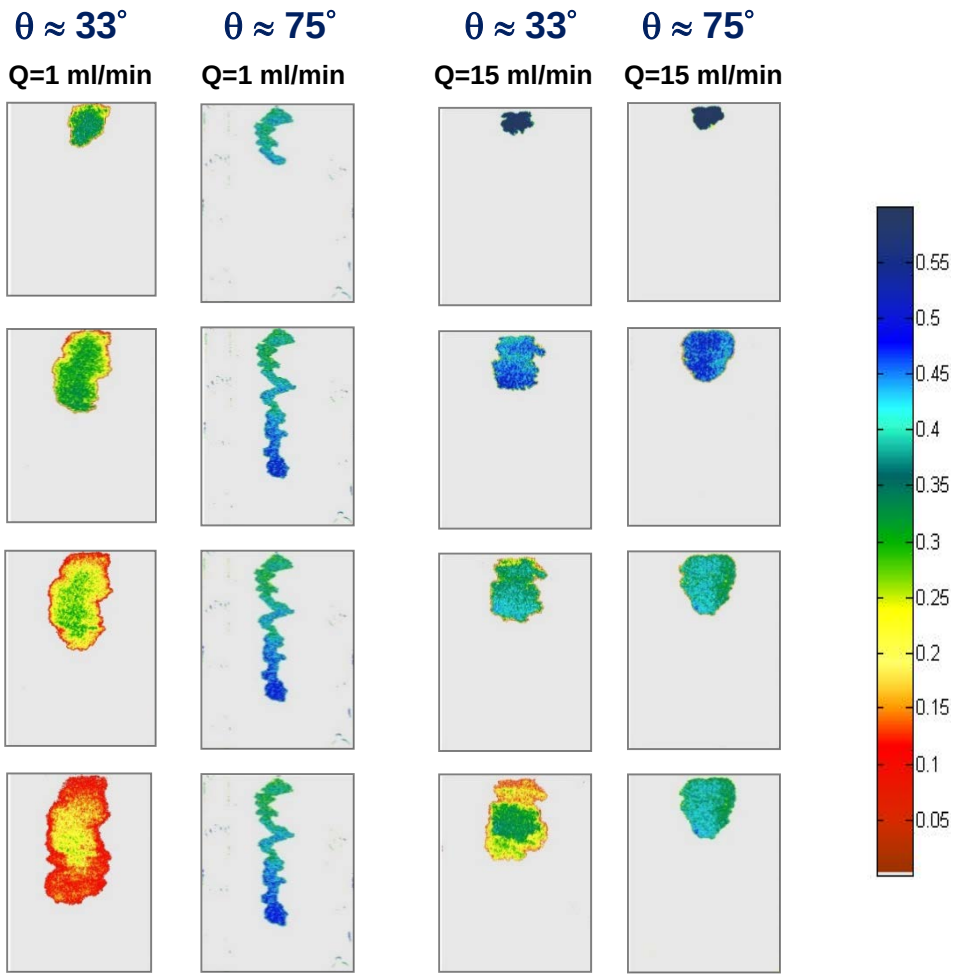
1 h redistribution

2 and 10 h redistribution

Xiong et al., *J. Hydrol* 2012

Should be the soil water repellent in order to generate fingered (unstable) flow?





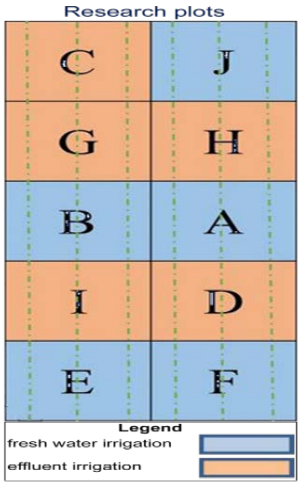
Wallach et al., *WRR* 2013

Given that continuous TWW render soils water repellent or sub-critically repellent with uneven spatial water distribution, the following questions follow:

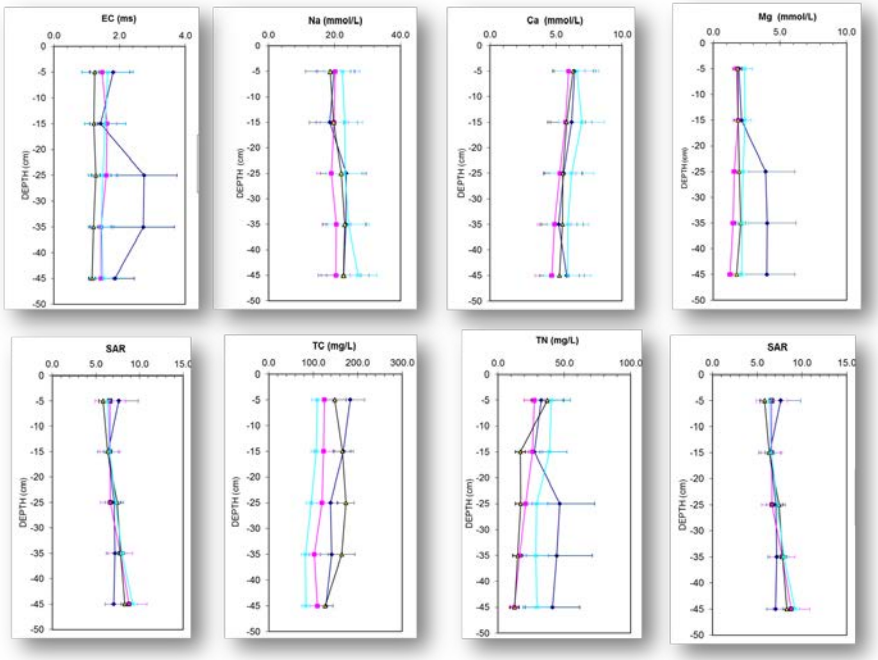
1) How does effluent-irrigation-induced soil water repellency affect the spatial and temporal distribution of chemicals in the root zone, and to what extent?
2) Can a replacement of TWW by FW irrigation reduce the soil wettability effects?

The Sitriya commercial citrus orchard study 2012-today

2008 → 2012



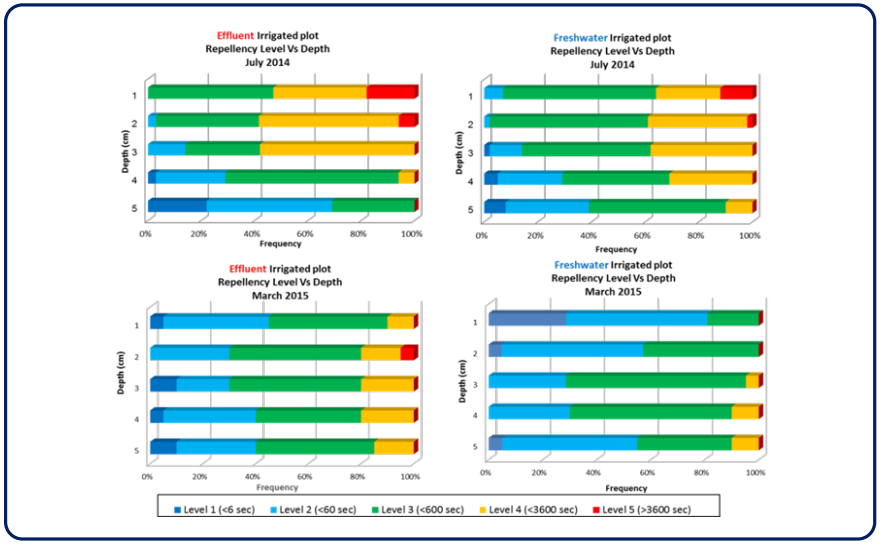
Sitriya commercial Citrus orchard



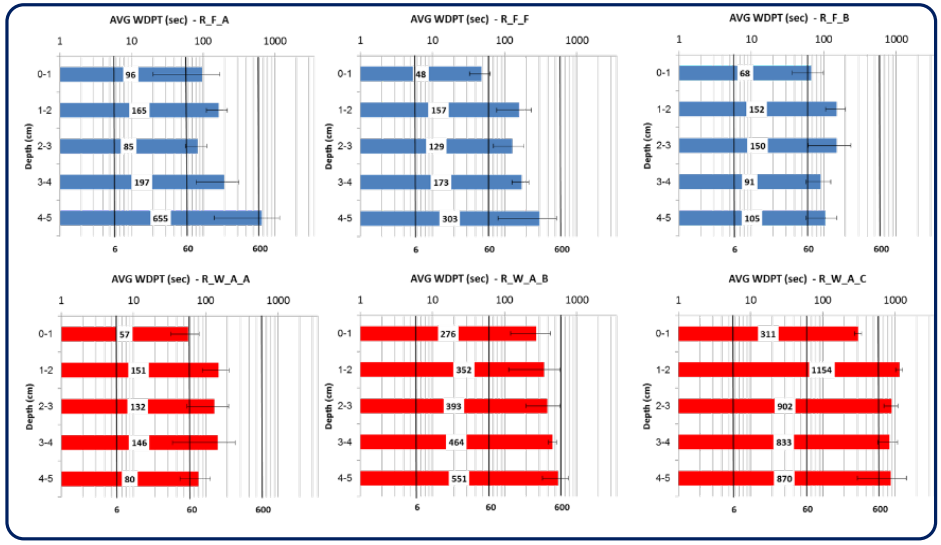
10 plots*4 profiles per plot*5 layers per profile = 200 samples analyzed for: Na, K, Ca, Mg, pH, EC, TOC, TC, TI, TN, SAR

WDPT for the TWW and FW plots

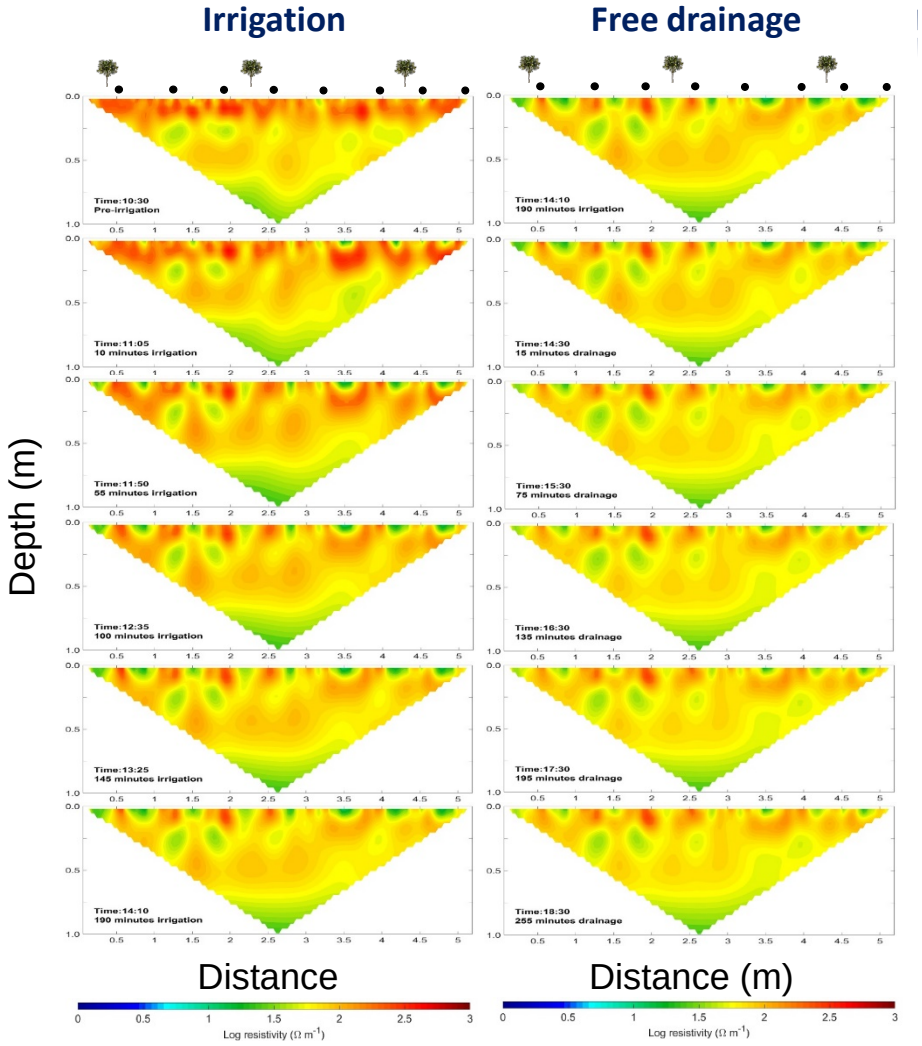
Sampling dates: July 2014 and Mach 2015



Sampling date: October 2015

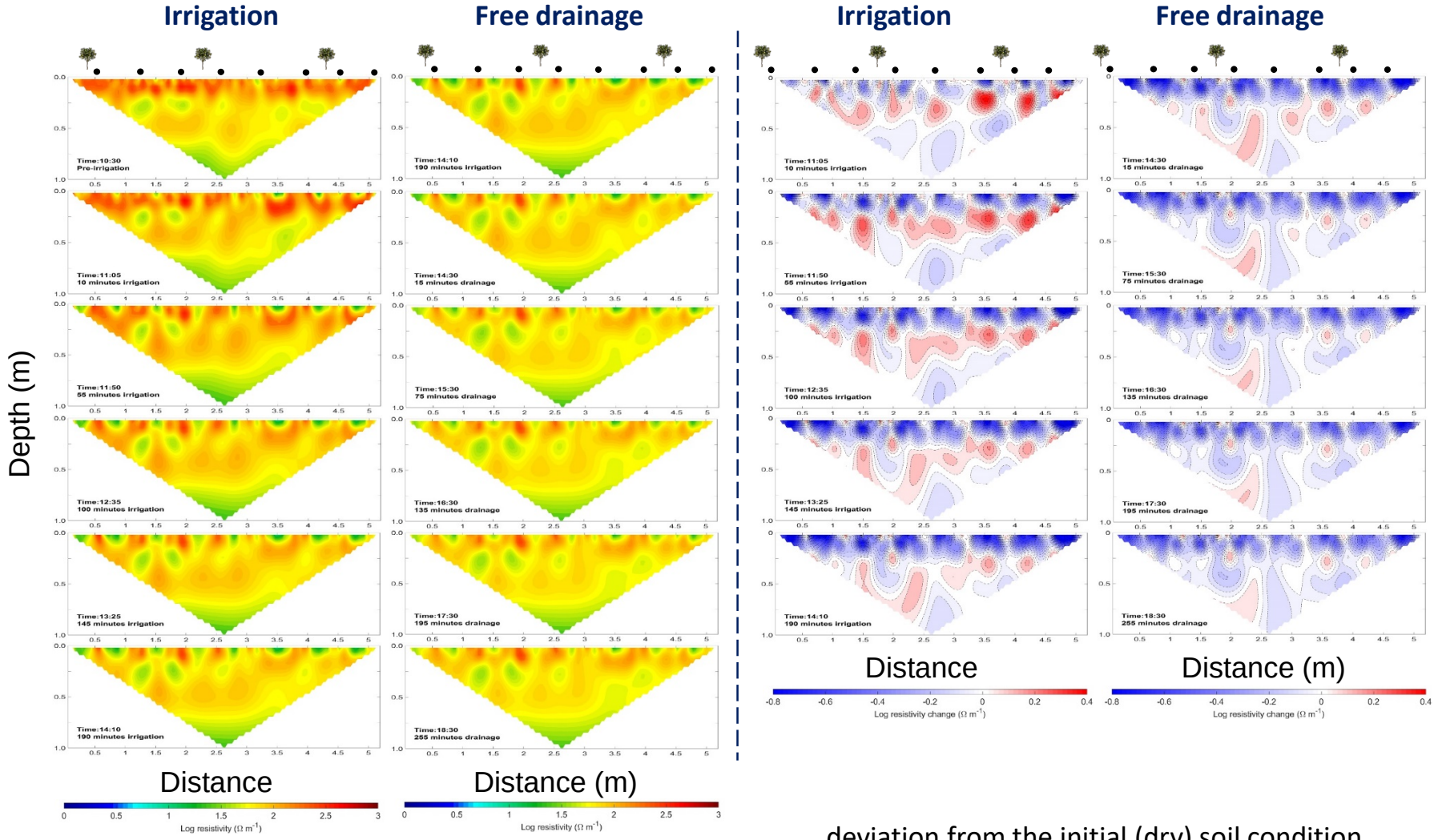


Spatial distribution of ER and net ER change in a TWW plot



0 g/L treated R1 Plot

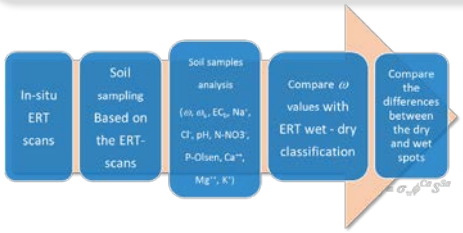
Spatial distribution of ER and net ER change in a TWW plot

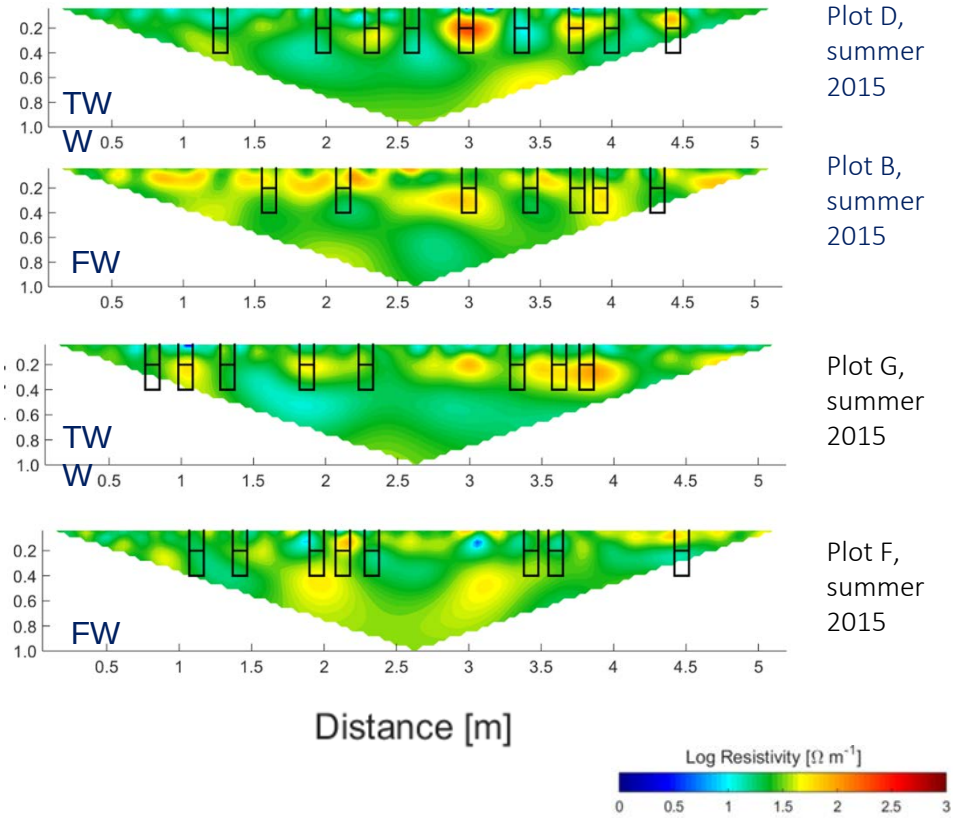


deviation from the initial (dry) soil condition

0 g/L treated R1 Plot

Soil sampling scheme based on preceding ERT surveys





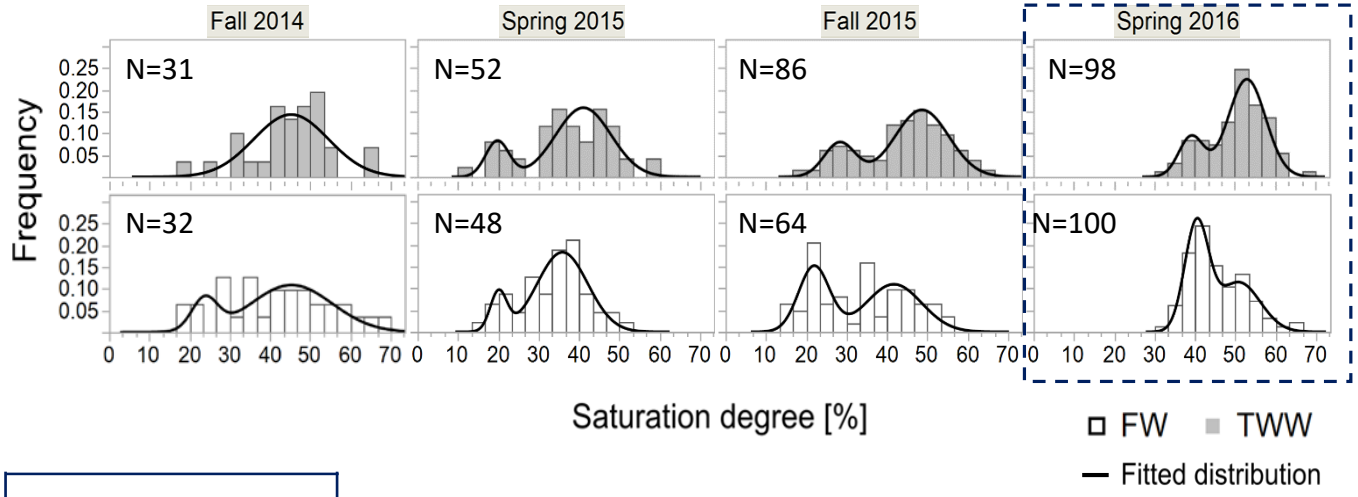
Plot D, summer 2015

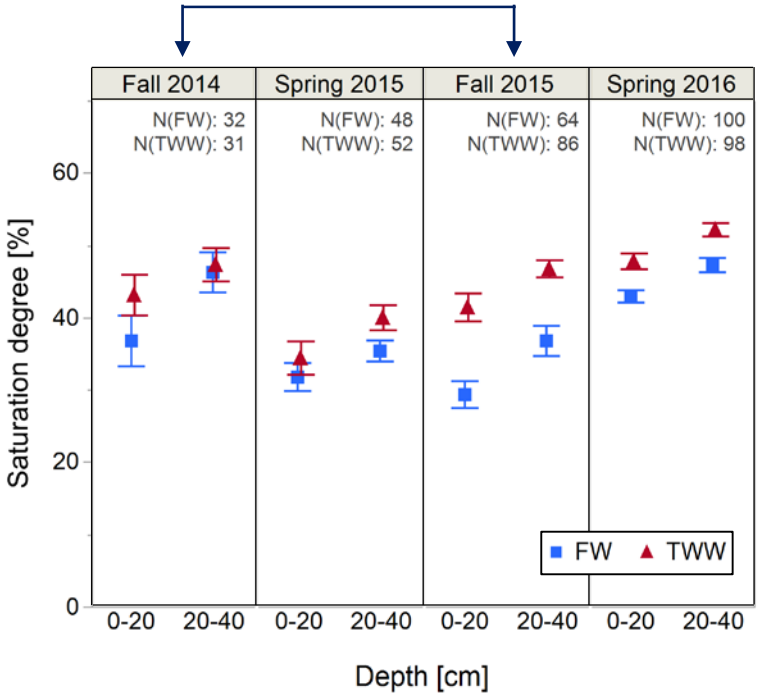
Plot B, summer 2015

Plot G, summer 2015

Plot F, summer 2015

Soil water content distribution - sampling based on preceding ERT scans





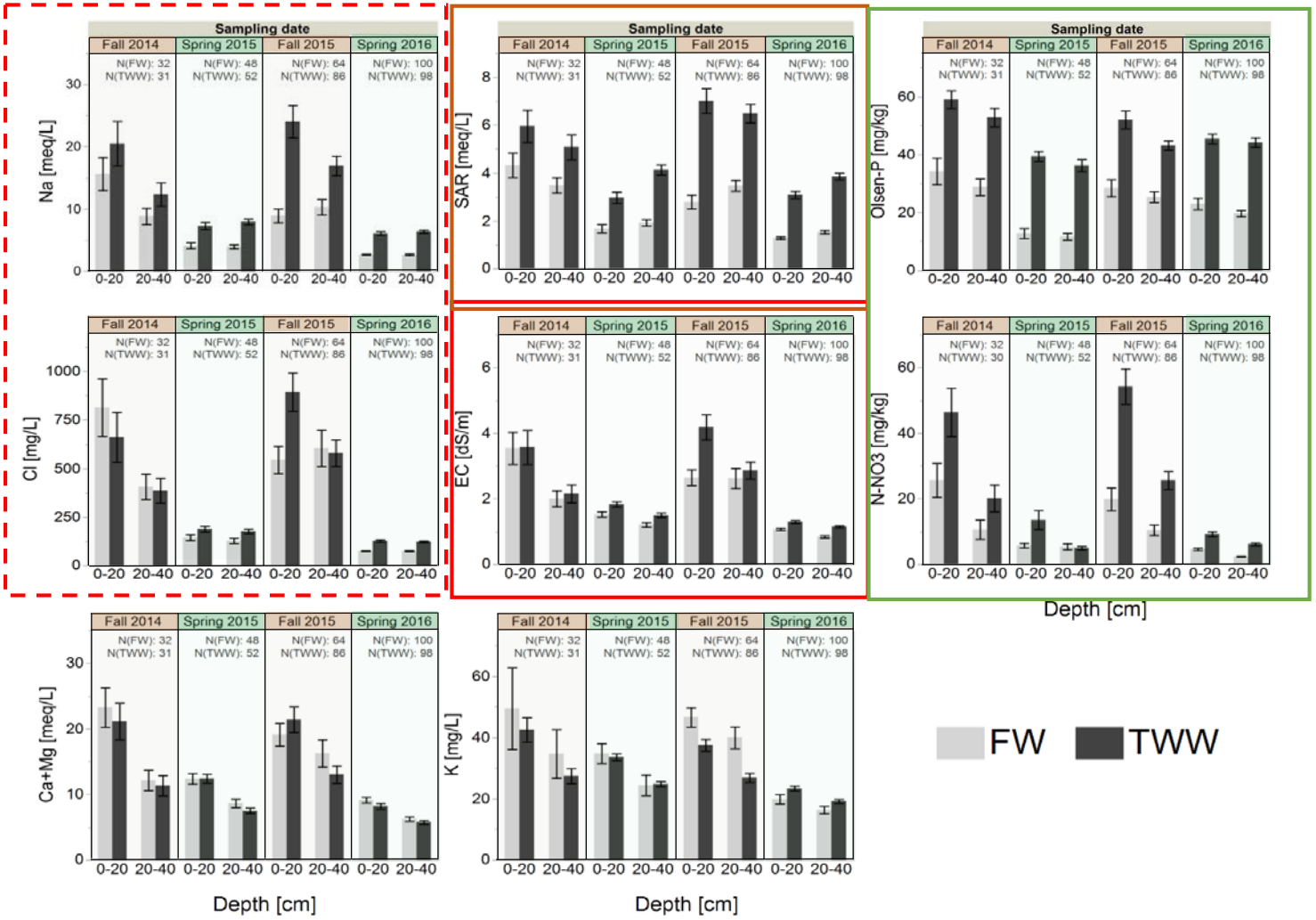
Rahav et al., *WRR* 2017

Chemical Properties of the TWW and FW

Water type	EC (dS/m)	Cl (mg/L)	Na (meq/L)	Ca+Mg (meq/L)	$N\text{-}NO_3$ (mg/L)	$N\text{-}NH_4$ (mg/L)	P (mg/L)	K (mg/L)	SAR $(meq/L)^{0.5}$
TWW	1.55 (0.06)	204.48 (7.38)	7.16 (0.09)	4.80 (0.12)	<1.5	53.86 (0.15)	7.38 (0.23)	26.00 (0.11)	4.80 (0.45)
FW	0.77 (0.02)	108.20 (1.85)	2.84 (0.05)	5.38 (0.63)	<1.5	0.63 (0.06)	<0.1	3.58 (0.40)	2.00 (0.01)

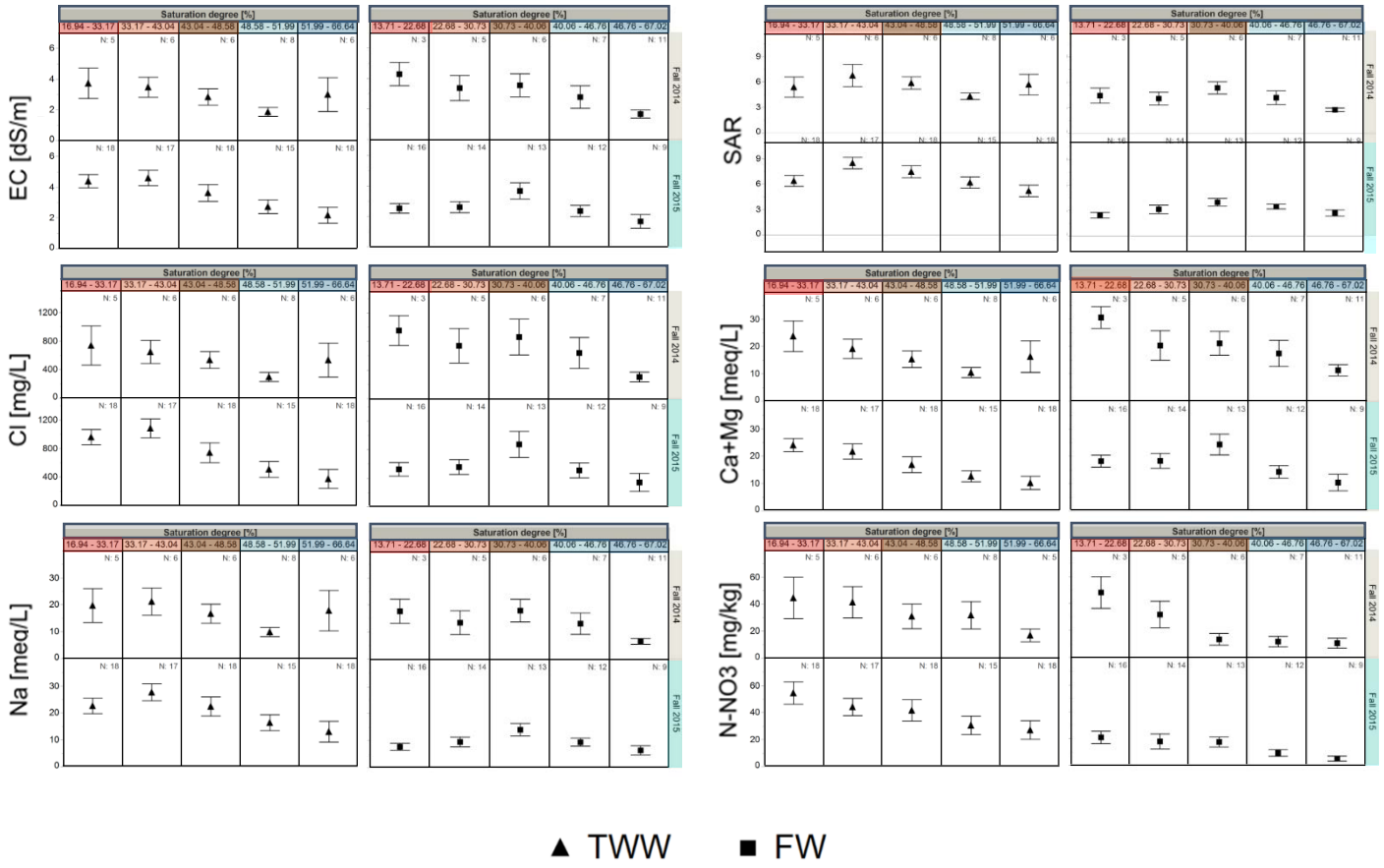
Mean values based on sampling as measured in March 2015 directly from drippers, prior to the application of fertilization through the irrigation water.

The water quality effect on chemical properties in the upper root zone



Rahav et al., *WRR* 2017

The effect of uneven flow in the root zone on chemical concentration distribution



Rahav et al., *WRR* 2017

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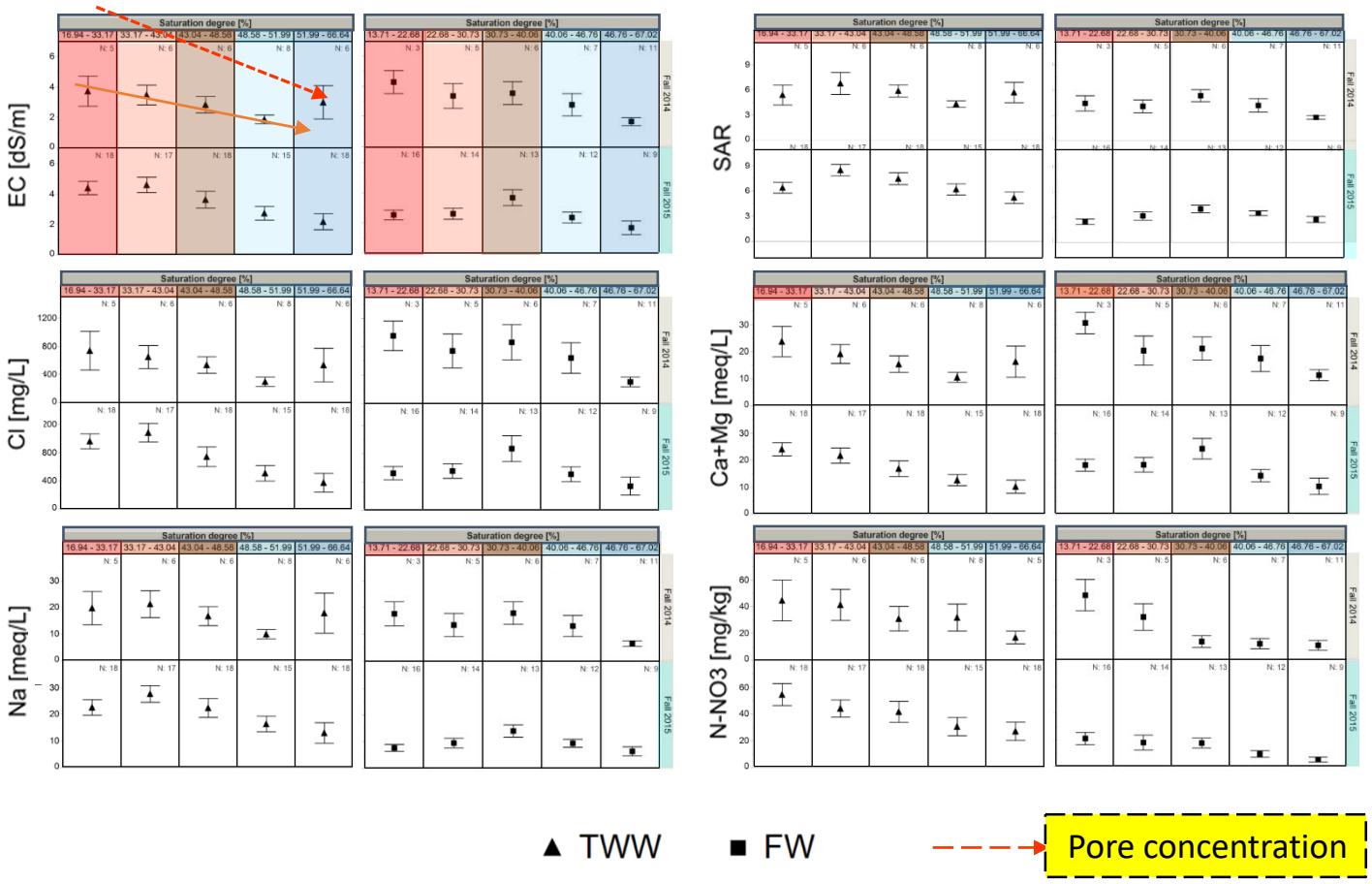

Rahav et al., *WRR* 2017

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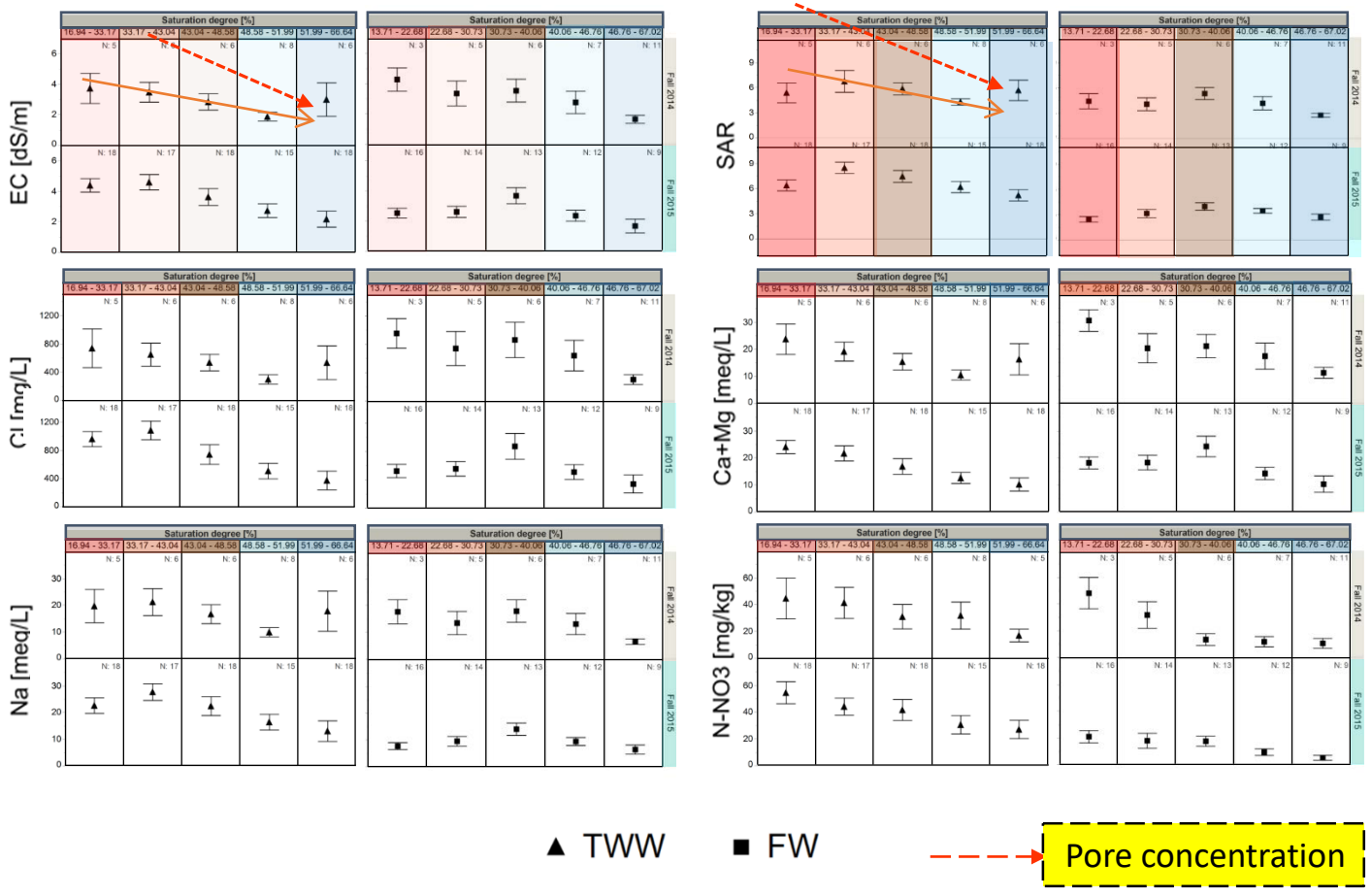

Rahav et al., *WRR* 2017

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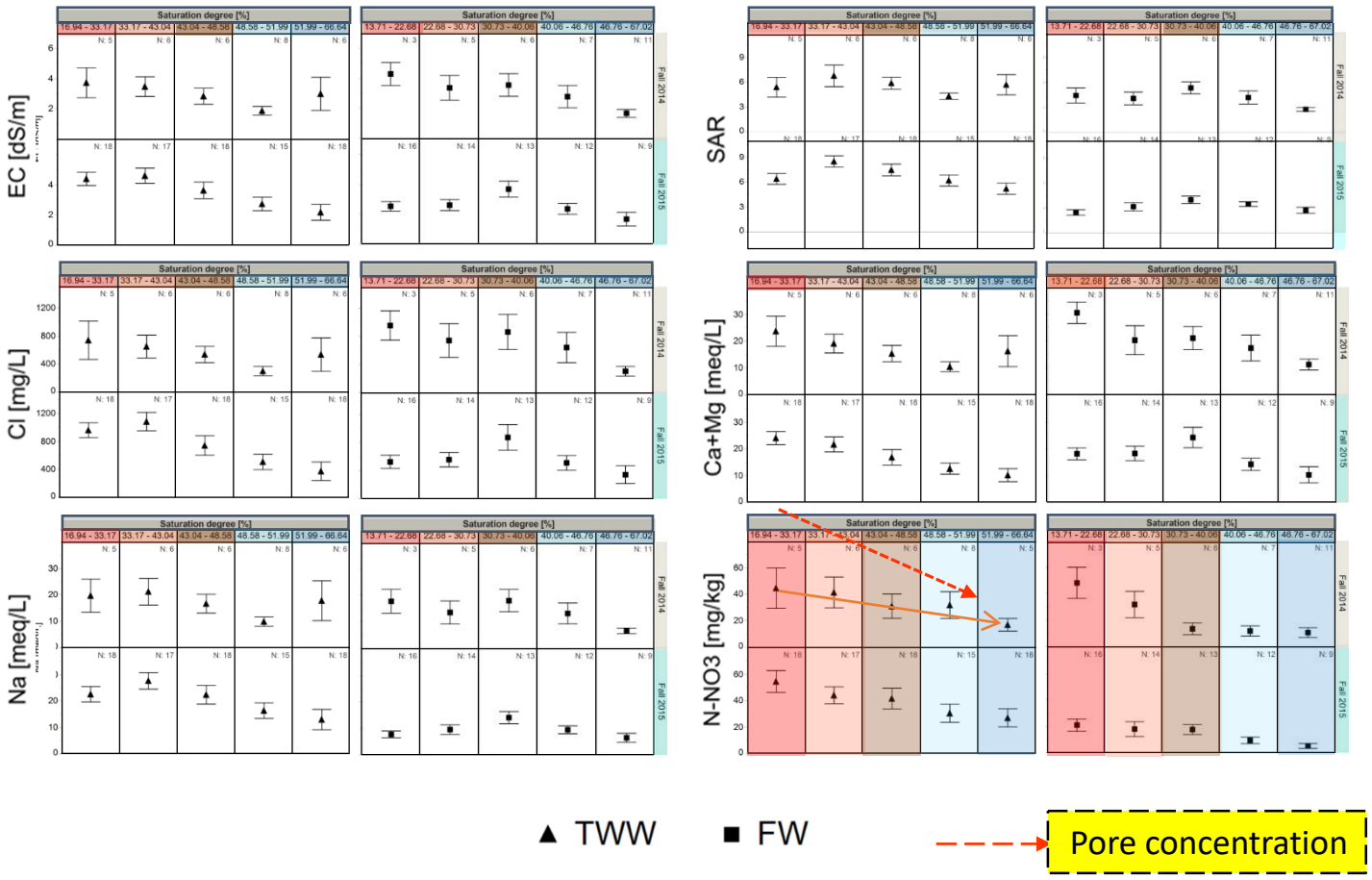

Rahav et al., *WRR* 2017

Conclusions

- TWW irrigation renders the soil hydrophobic that induces the formation of preferential flow pathways with drier soil volume among them.
- The preferential flow regime leads to uneven chemical distribution in the soil profile, with substantially higher concentrations at the dry spots that may reach toxic values.
- The way trees are coping with adjacent zones with high and low concentrations is an unknown so far.
- Beyond the reduction of salinity and other nutrient input, the replacement of TWW by FW gradually decreases soil water repellency and its associated effects on the spatial water content and chemical distribution in the root zone.

THE HEBREW UNIVERSITY OF JERUSALEM

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מועצת הצמחים
המועצה לייצור צמחים ולשיווקם
The Plants Production and Marketing Board

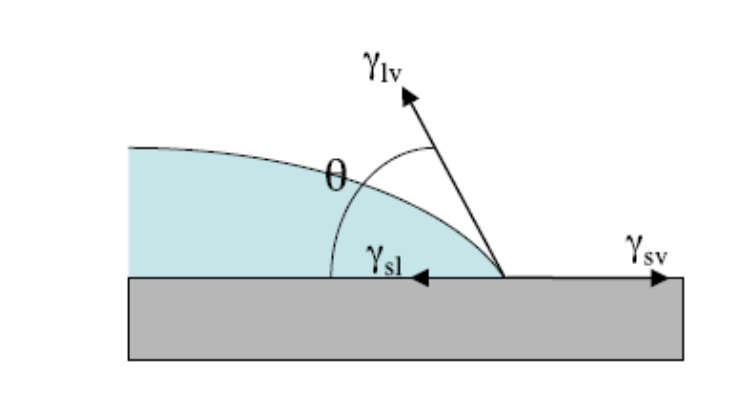
mehadrin
Growers at heart

Soil water repellency

Contact angle of a sessile drop

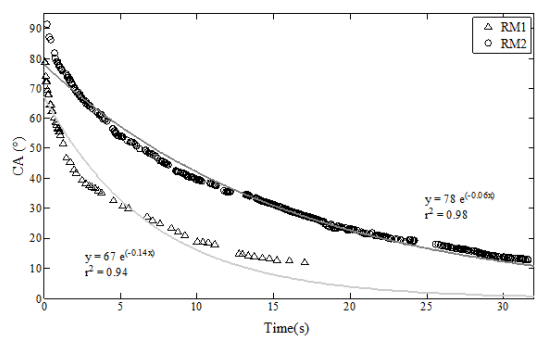
Young's equation - a mechanical force balance on the three-phase contact line:

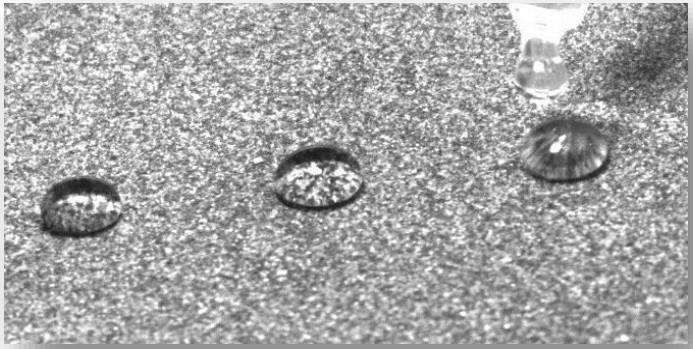
$$cos\theta_{eq} = \frac{\gamma_{sv} - \gamma_{sl}}{\gamma_{lv}}$$



θ > 90° = WR
θ < 90° ≠ WR

WDPT test on a soil surface





If DPT > 5 s = SWR
If DPT < 5 s ≠ SWR