

Irrigation with treated waste water in the Holy Land: Blessings and Curses

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Agricultural Research Organization – Volcani Center

Institute of Soil, Water and Environmental Sciences

Ministry of Agriculture & Rural Development

The State of Israel

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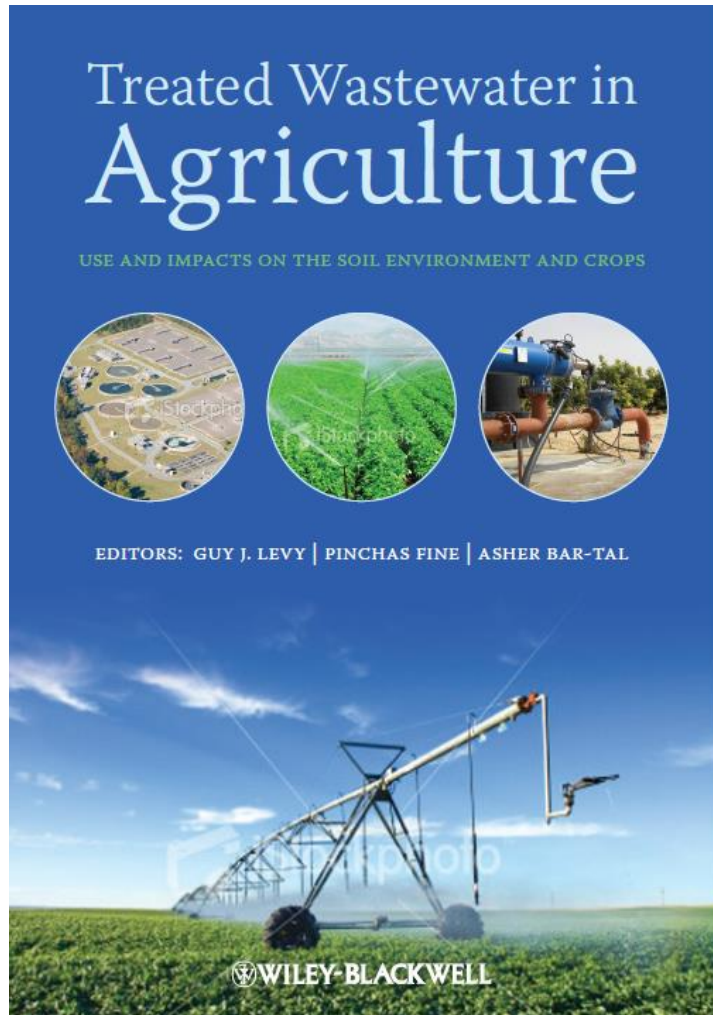


Agricultural Engineering

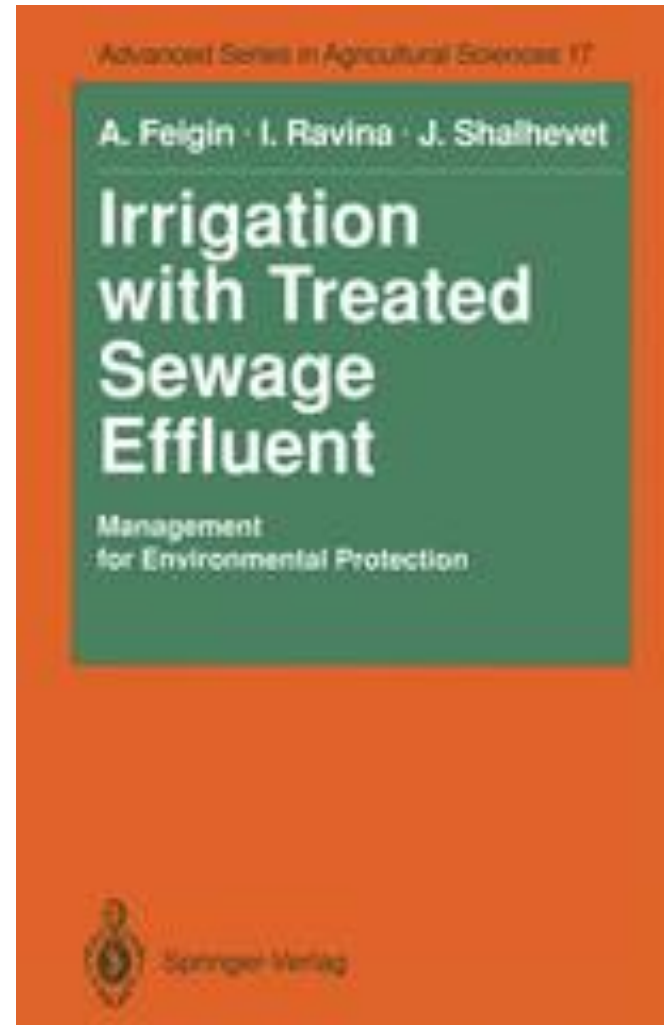


Postharvest and Food
Sciences

The textbooks on this subject were written by
ARO scientists



2010



1991

Israel has overcome aridity in Agric. by developing water resources

Israel's national water carrier:

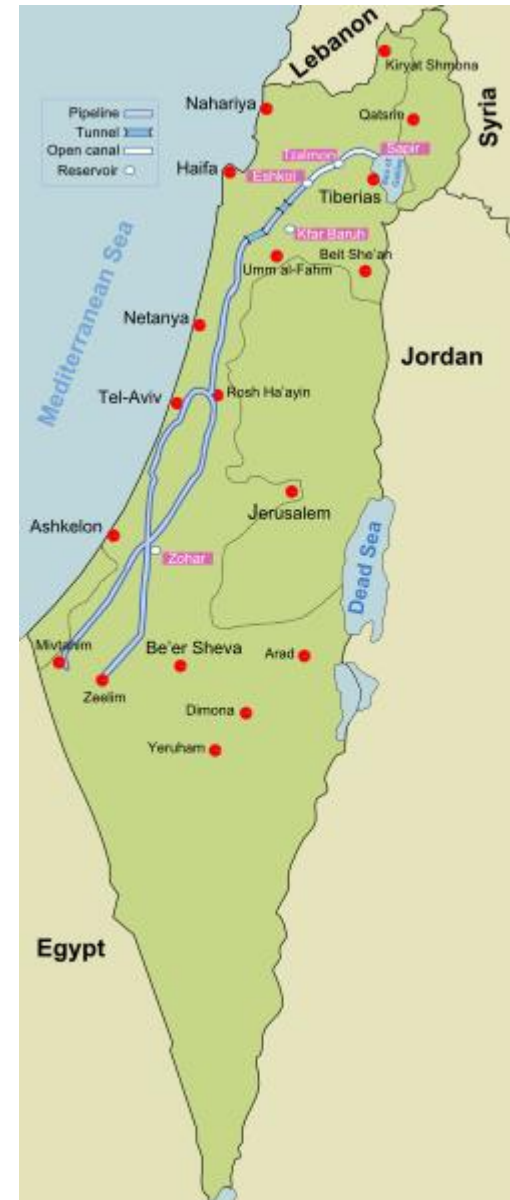
Completed in 1964, conveys up to $\sim 350 \text{ Mm}^3$ water per year from the Kinneret (Sea of Galilee).

At first 80% for agriculture and 20% for drinking
Currently 80% for drinking and 20% for Agriculture

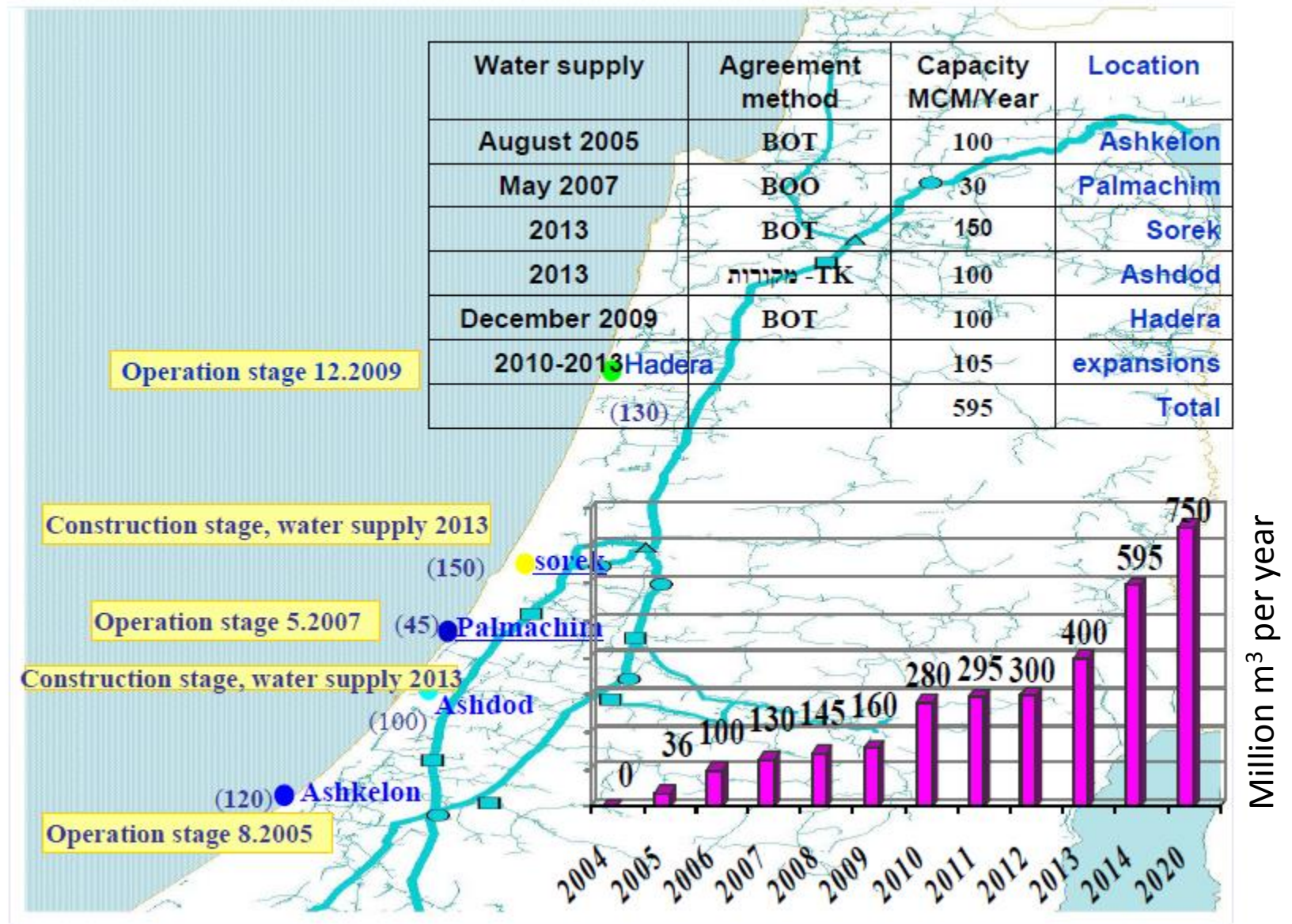
Led to land use changes, since much land in the center and south became irrigated.

Documented decreases in surface albedo for extensive areas in the center and south may have contributed to surface warming.

The water carrier became the backbone of the national water supply system

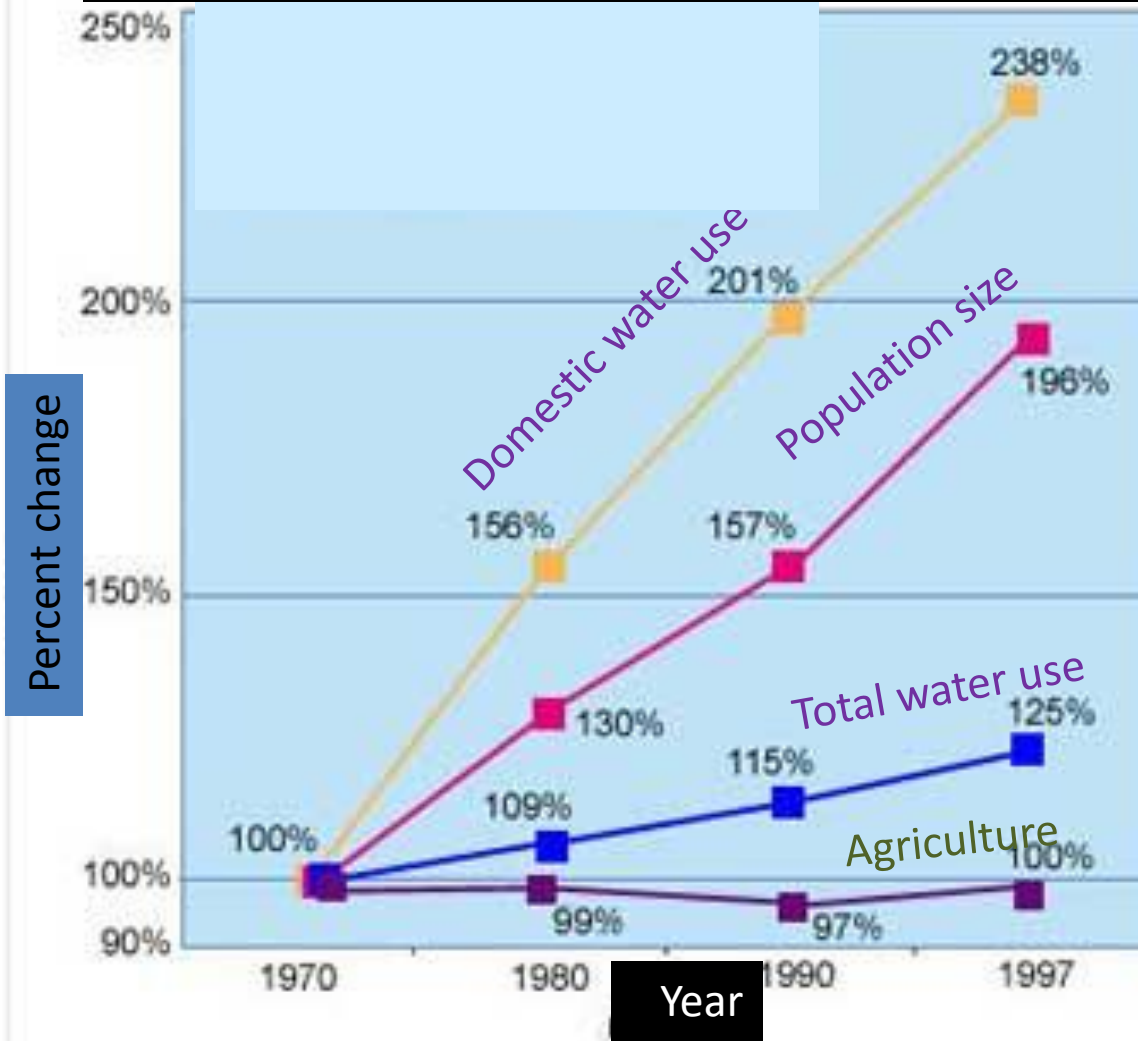


Sea Water Desalination



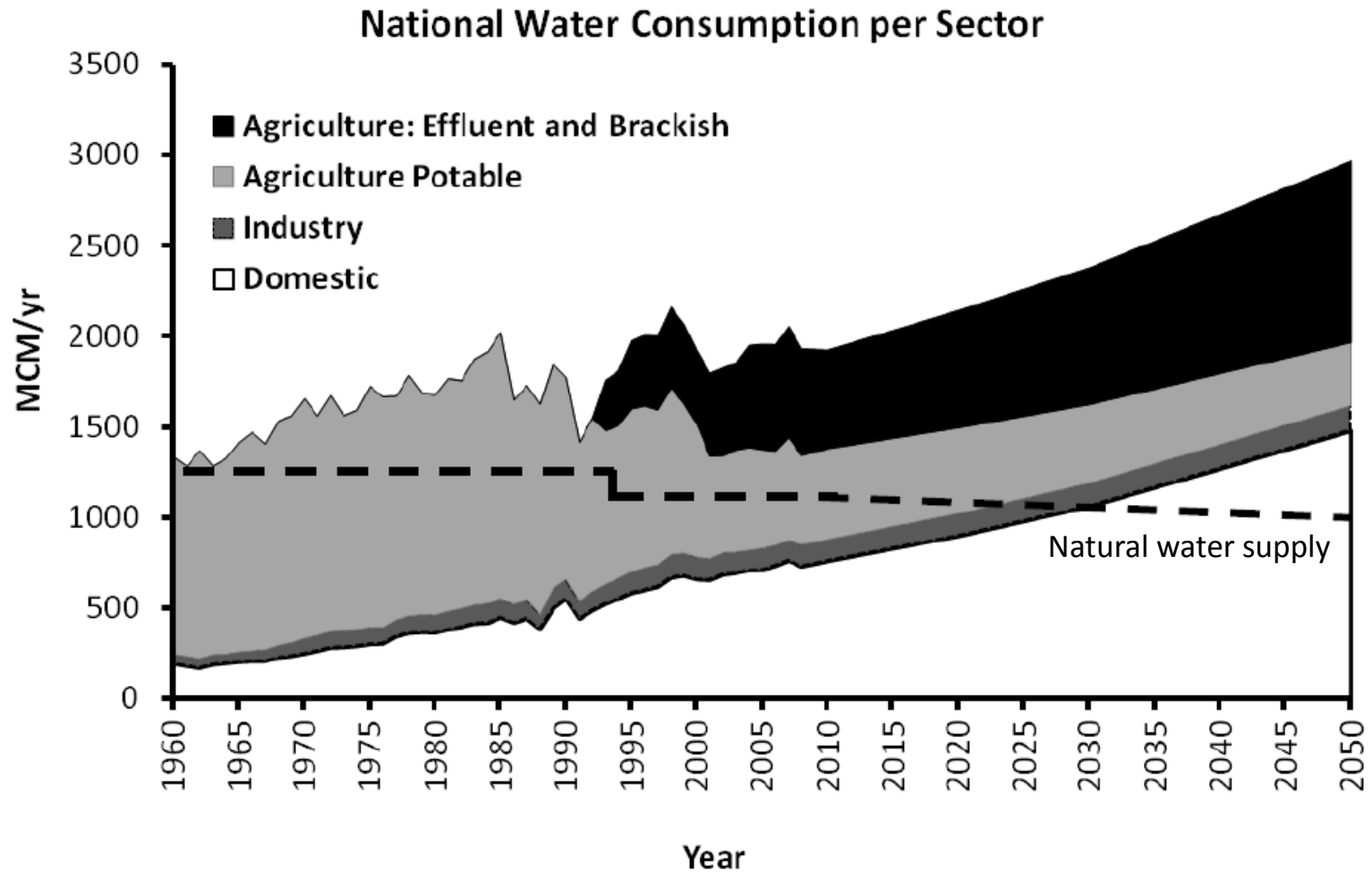
Source: Tenne 2011

Distribution of population growth and water use in % relative to 1970



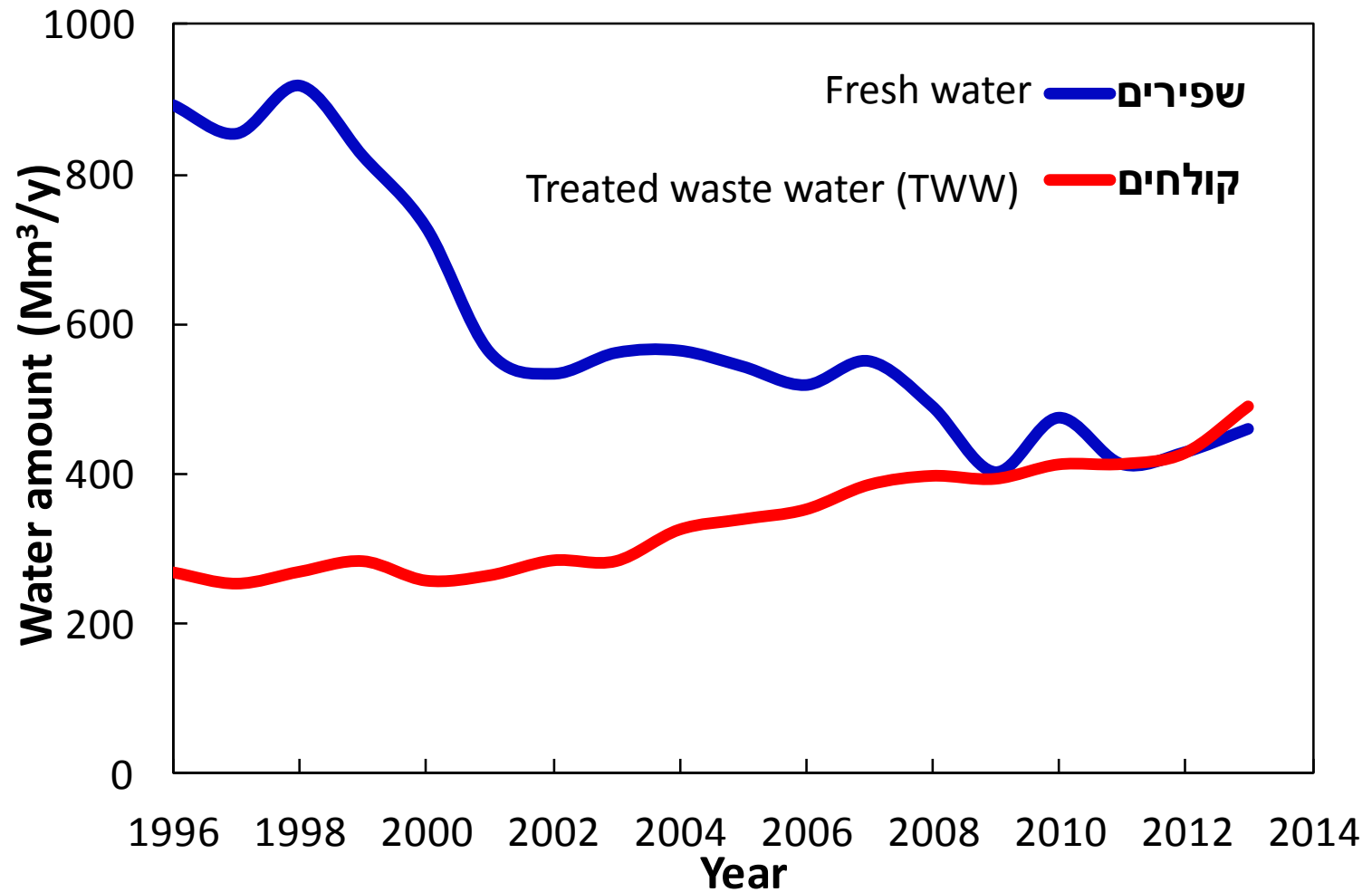
Note: More recent Avg agricultural water use was similar to 1970, and about half was recycled wastewater

Water quality and allocation timeline



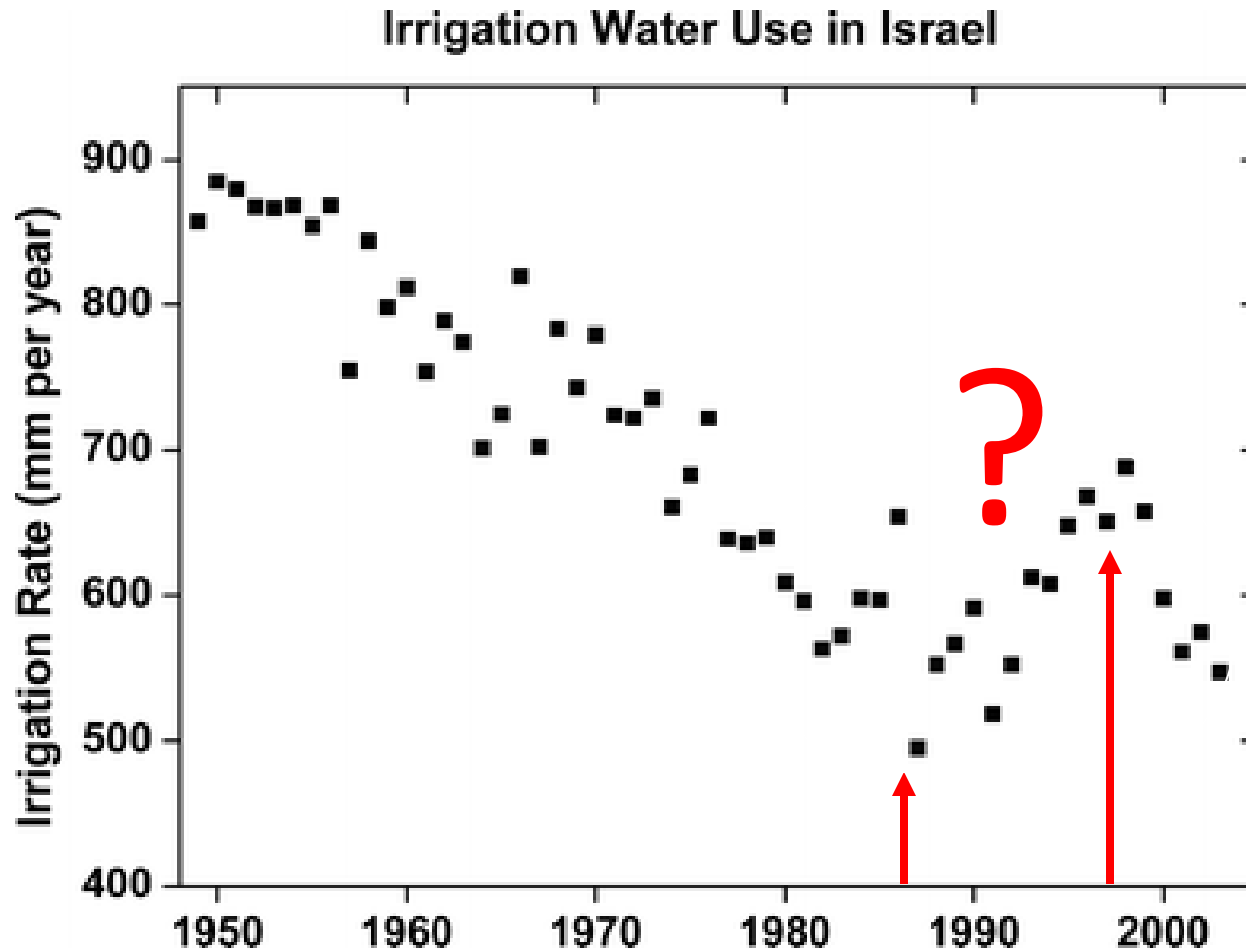
From: Long term plan, Israel Water Authority

Israel: Agriculture Water Consumption vs. Time by Source



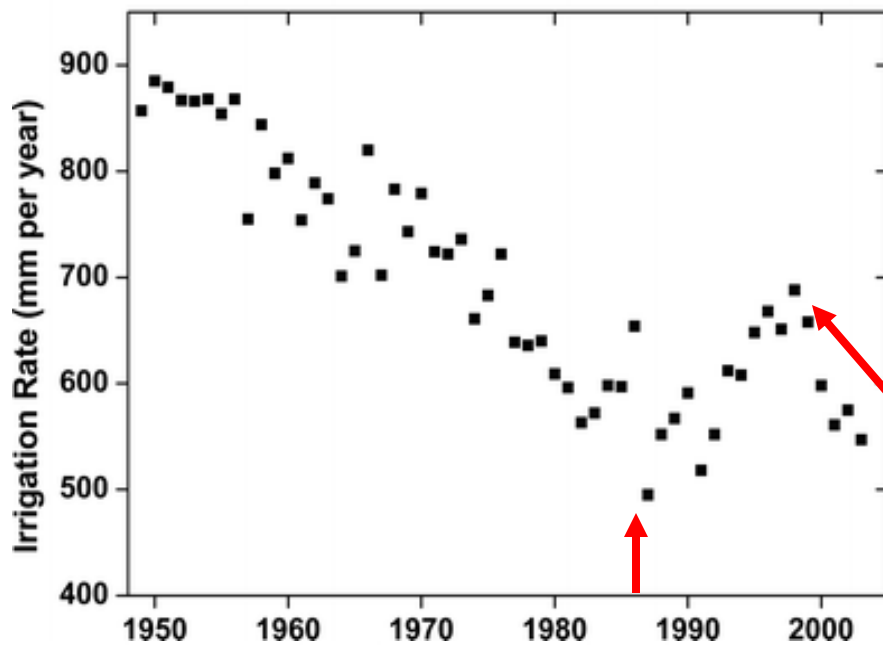
(רשות המים, 2013)

A case study – Fuchs (2006)*

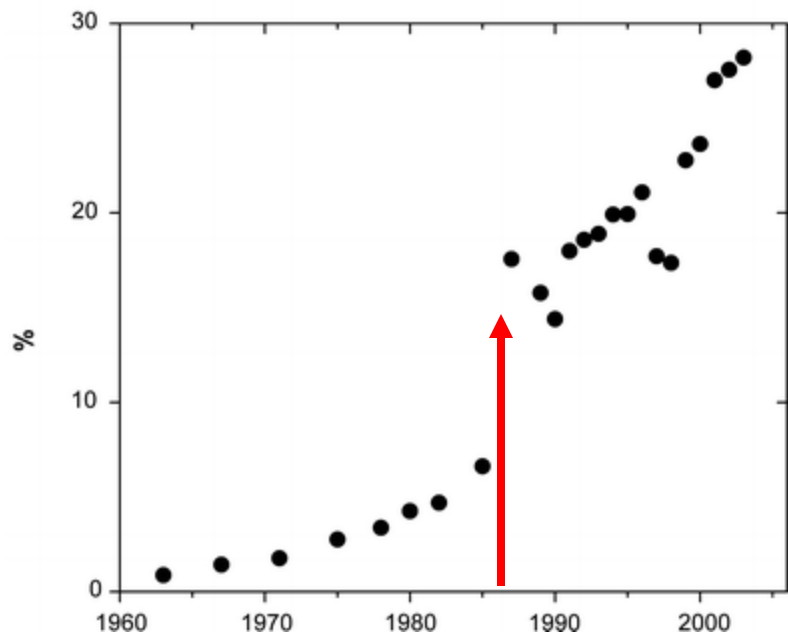
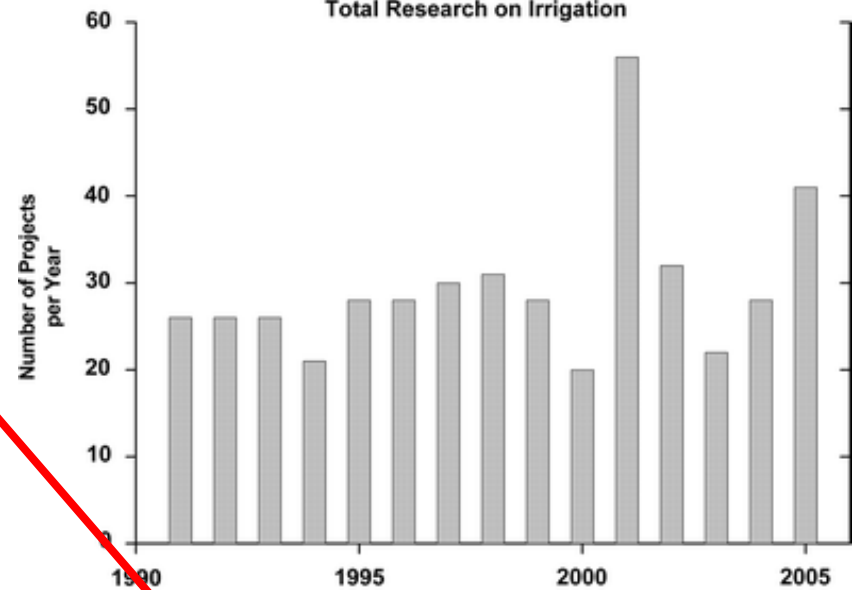


* Irrigation science, 2006

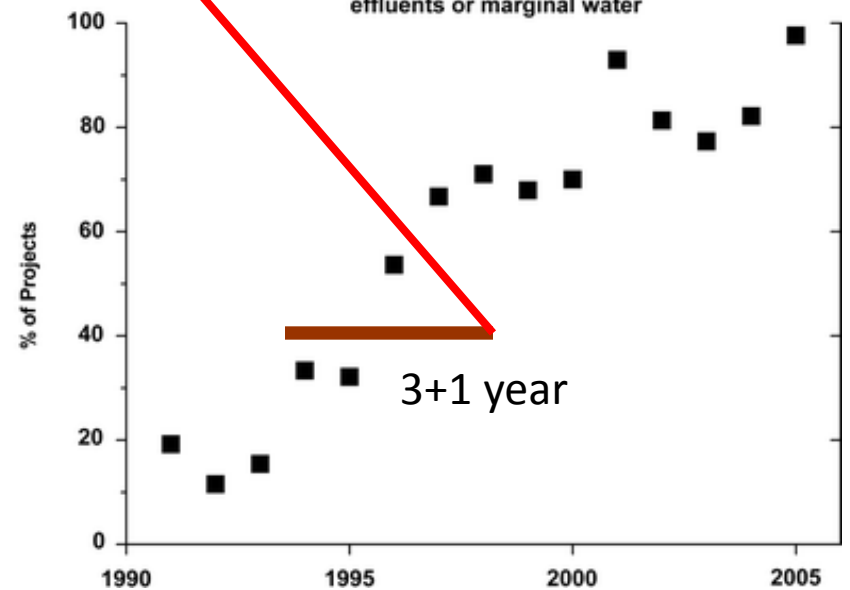
Irrigation Water Use in Israel



Total Research on Irrigation



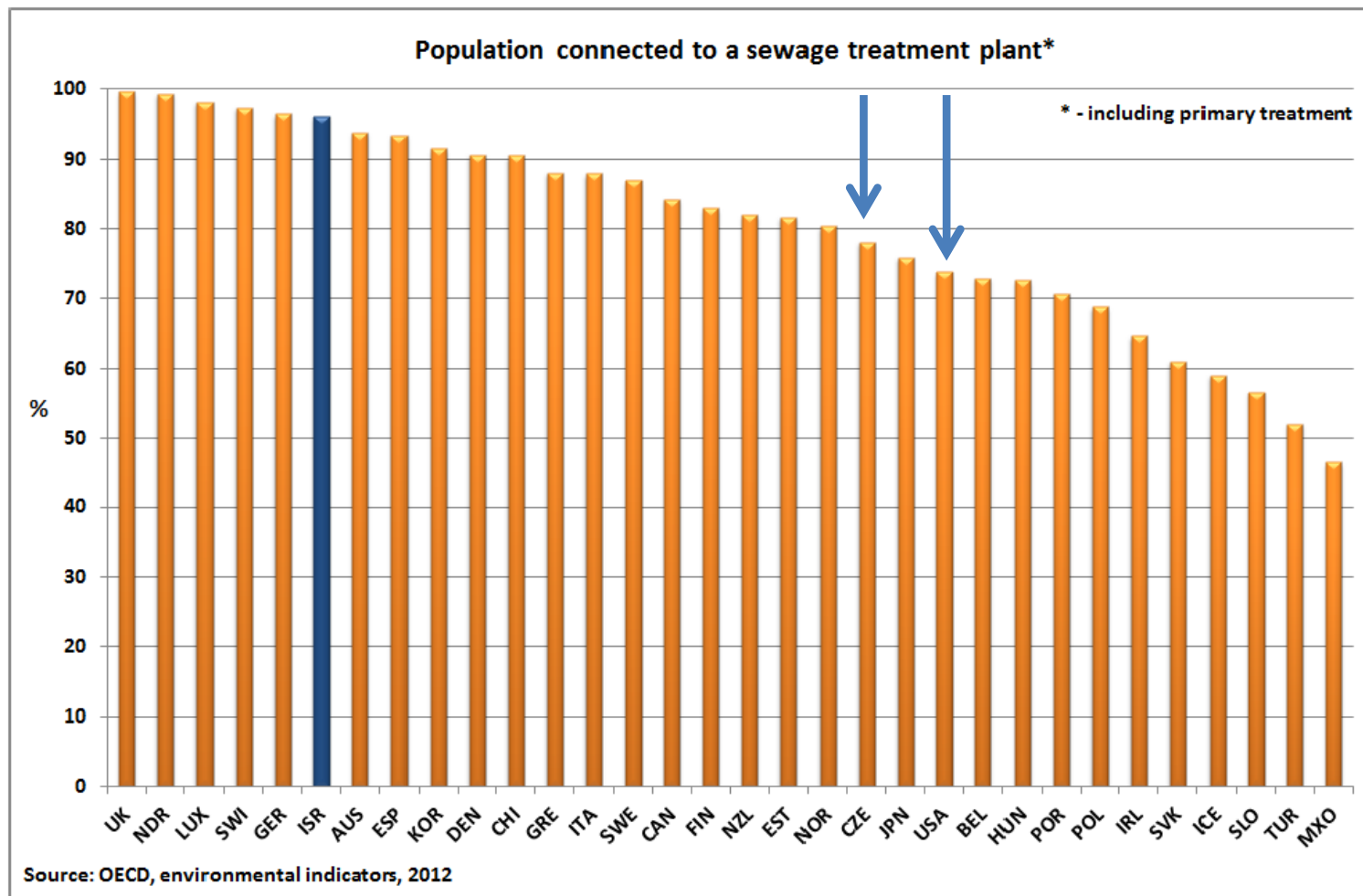
Research on Irrigation with effluents or marginal water



Synopsis:

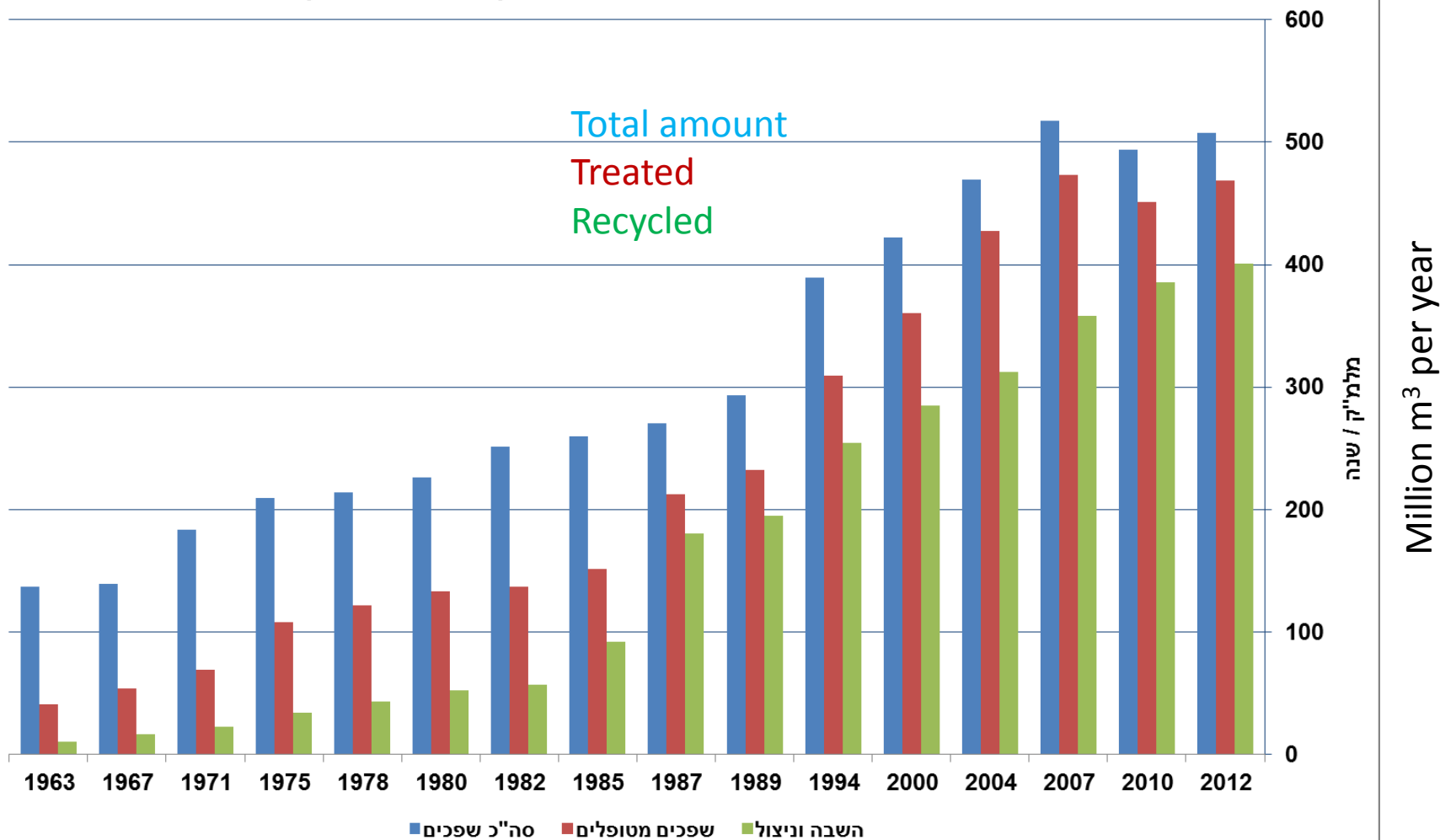
- 1986 – large influx of treated effluents for irrigation from new waste water treatment facilities. This was essentially a step change.
- Farmers over-irrigated to prevent accumulation of salts and other problems.
- Large research effort starting around 1994 – followed by application in the extension service.
- New knowledge allowed lowering irrigation starting around 1998.
- Estimates of water savings show that the return on research spending was 10 times.

OECD 2012 - % POPULATION CONNECTED TO SEWAGE TREATMENT



Waste water collection, treatment and recycling in Israel 1963-2012

איסוף וטיפול בשפכים וניצול קולחים (1963-2012)



Waste water treatment technologies

- Treatment in Israel is either **secondary (bringing water to irrigation standards)** or more recently **tertiary (bringing water to drinking standards, except for bacterial quality)**.



Blessings and Curses of using TWW in Agriculture

- Blessings:

- A large water resource
- Nitrogen and other elements can be used by plants.
- Fertilizer reductions and reduced Greenhouse Gas Emissions
- Reduced pollution of rivers and ocean

- Curses:

- Expensive
- Osmotic and specific ion toxicity to plants, specifically from salinity, Cl, Na and B.
- Damage to soil structure:
 - Reduced water infiltration
 - Reduced soil aeration resulting in reduced O₂ for roots, reducing conditions and nitrate accumulation.
- Groundwater pollution

Selected properties of the soils at two experimental sites Ramat Hakovesh (RK) and Mizra (MA). Values in parenthesis are standard deviations. Lado et al. 2012. SSSAJ 76:1358-1369

			Ramat Hakovesh	Mizra
Texture			Sand	Clay
Taxonomy			Typic Haploxeralf	Chromic Haploxerert
Mechanical	sand	g kg ⁻¹	880 (39)	120 (17)
composition	silt	g kg ⁻¹	20 (3)	210 (19)
	clay	g kg ⁻¹	100 (9)	670 (13)
CaCO ₃		g kg ⁻¹	Tr [†]	103 (5)
Clay	Smectite		5	5
mineralogy‡	Illite		1	1
	Kaolinite		3	3

Selected properties of freshwater and secondary treated wastewater (TWW) used for irrigation at two experimental sites - Ramat Hakovesh (RK) and Mizra (MA). Values in parenthesis are standard deviations. Lado et al. 2012. SSSAJ 76:1358-1369 .

Variable	Units	Ramat Hakovesh/sand		Mizra/ clay	
		TWW	Freshwater	TWW	Freshwater
pH		7.5 (0.3)	7.2 (0.2)	7.8 (0.2)	7.2 (0.2)
EC	dS m ⁻¹	1.8 (0.4)	0.9 (0.1)	2.6 (0.36)	1.0 (0.1)
SAR	(mmol _c L ⁻¹) ^{0.5}	3.8 (0.4)	1.5 (0.3)	4.8 (0.04)	2.5 (0.2)
HCO ₃ ⁻	mmol L ⁻¹	7.9 (0.3)	3.6 (0.2)	9.2 (0.07)	4.9 (0.3)
Cl ⁻	mmol L ⁻¹	6.1 (0.5)	3.0 (0.2)	9.6 (2.0)	7.1 (0.9)
DOM	mg L ⁻¹	138.2 (67)	4.3 (1.7)	35.3 (0.22)	≈0

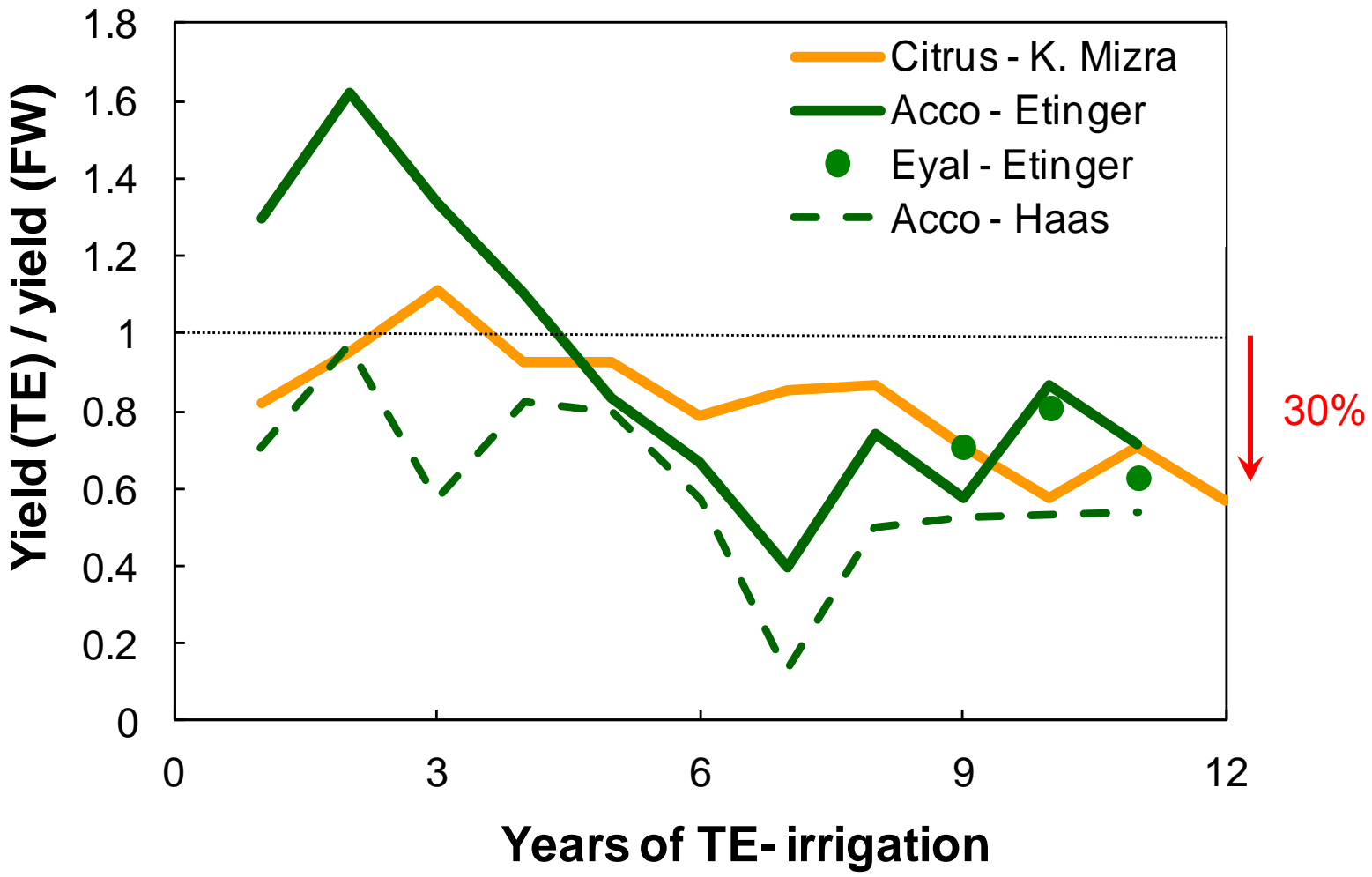
Selected properties of freshwater and secondary treated wastewater (TWW) used for irrigation at two experimental sites - Ramat Hakovesh (RK) and Mizra (MA). Values in parenthesis are standard deviations. Lado et al. 2012. SSSAJ 76:1358-1369 .

Variable	Units	Ramat Hakovesh/sand		Mizra/ clay	
		TWW	Freshwater	TWW	Freshwater
NH ₄ -N	mg l ⁻¹	32.4 (10.1)	0.16 (0.04)	42.6 (0.07)	≈0
NO ₃ -N	mg l ⁻¹	0.05 (0.09)	4.9 (1.9)	0.3 (0.74)	1.5 (0.2)
PO ₄ -P	mg l ⁻¹	7.5 (3.0)	0.04 (0.03)	13.7 (0.86)	0.04 (0.02)
K	mg l ⁻¹	31.2 (5.0)	0.2 (0.08)	74.1 (3.0)	6.2 (0.7)
B	μg l⁻¹	220 (60)	110 (40)	1,015 (250)	100 (12)
Cu	μg l ⁻¹	11 (5)	1.0 (0.4)	31.1 (0.58)	B.D.V.‡
Fe	μg l ⁻¹	320 (160)	20 (8)	418.1 (0.17)	9 (0.8)
Zn	μg l ⁻¹	144 (88)	57 (4.5)	145 (45)	54 (7.8)

Are there problems with TWW irrigation?

- In Israel, rainfall is only in the winter. We expect that detrimental factors from irrigation will accumulate during the summer dry (irrigation) season, but be washed out of the root zone in the winter.
- Are there immediate problems with irrigation, and is there long term accumulation of problems?

Long term effects of TWW/TE irrigation on orchards on CLAY soils



(Courtesy of Asher Aizenkot, Anat Lowengart, Ami Lahav, Myriam Zilberstein, and Udi Gafni)

The problem:

Recent orchard yield decline and occasional orchard collapse in TWW irrigated orchards has caused some alarm.

Hypothesis:

Long term TWW irrigation damages soil properties in the root zone, especially in clay soils.

Research objectives:

Characterizing hydraulic properties of soils, soil aeration, and root growth and activity in these cases



Following are a sample of results from large interdisciplinary programs to investigate this

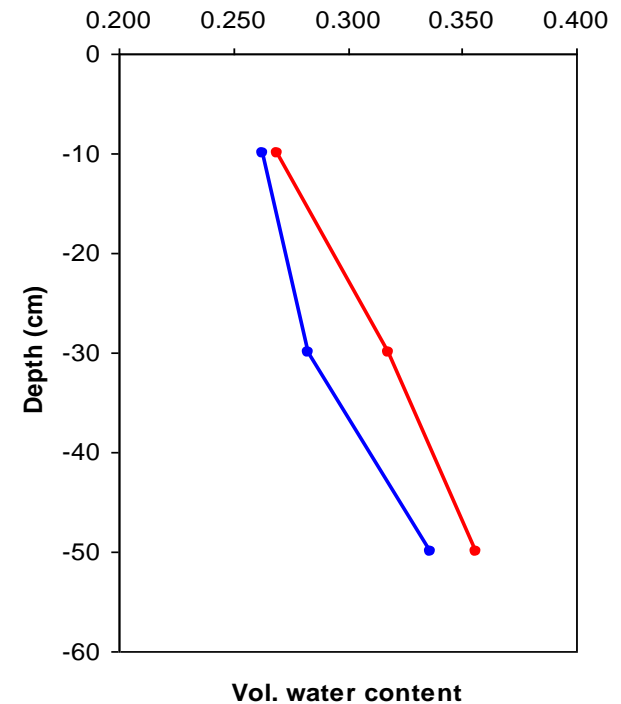
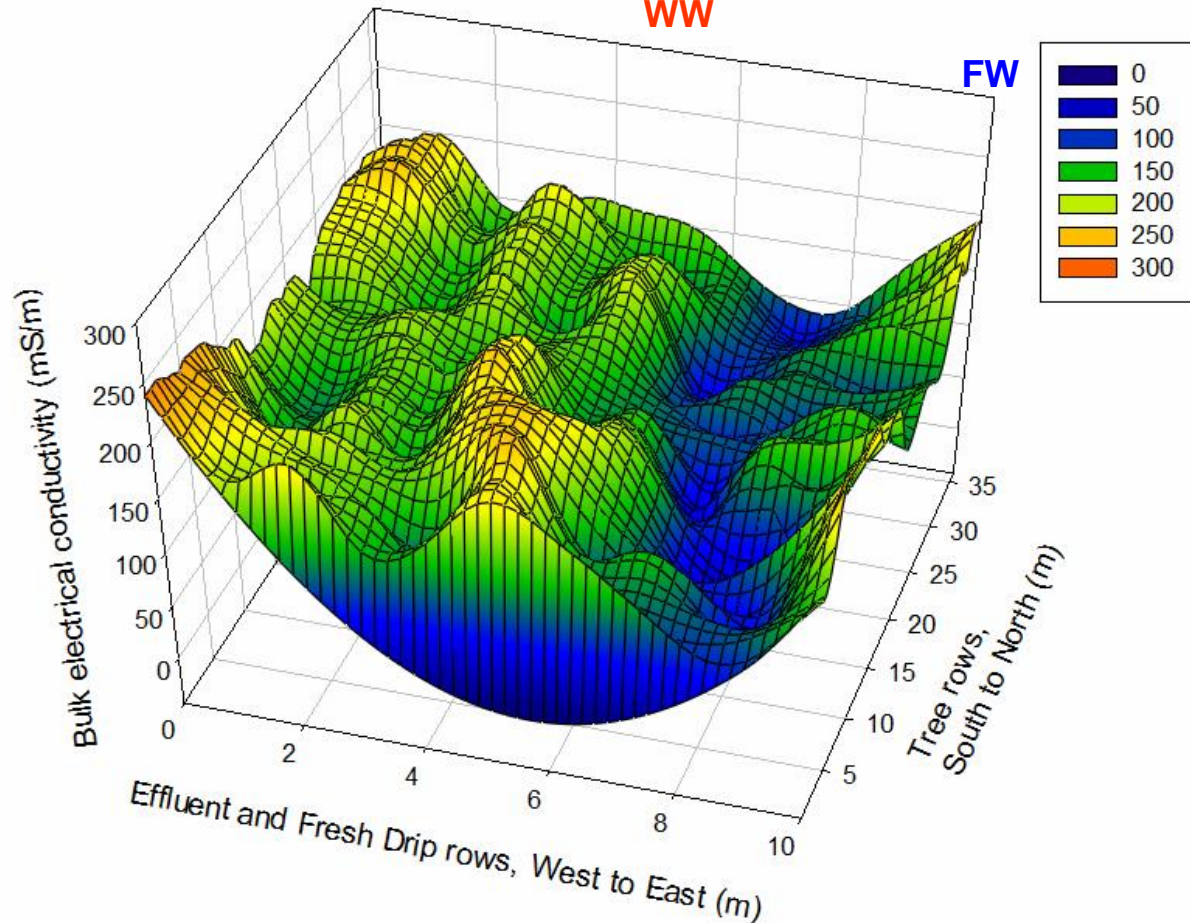
Soil water content and salinity in an avocado orchard at Akre: comparison between rows irrigated with TWW and Fresh Water. Measurements made with EMI proximal sensing.

Akko Avacado Orchard: VH II rows

26/6/2011

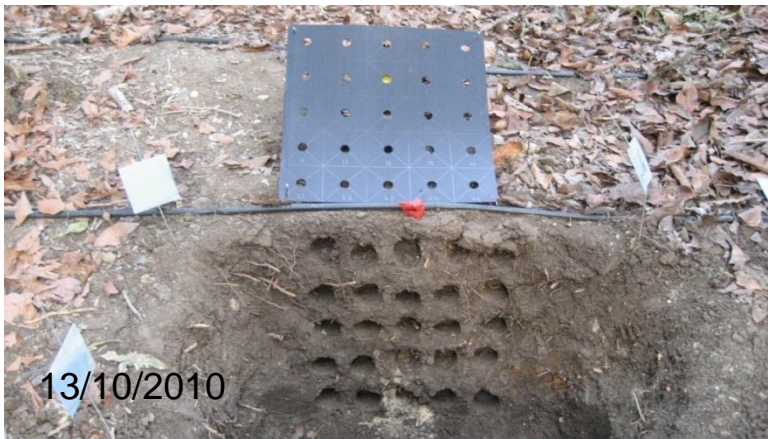
WW

FW



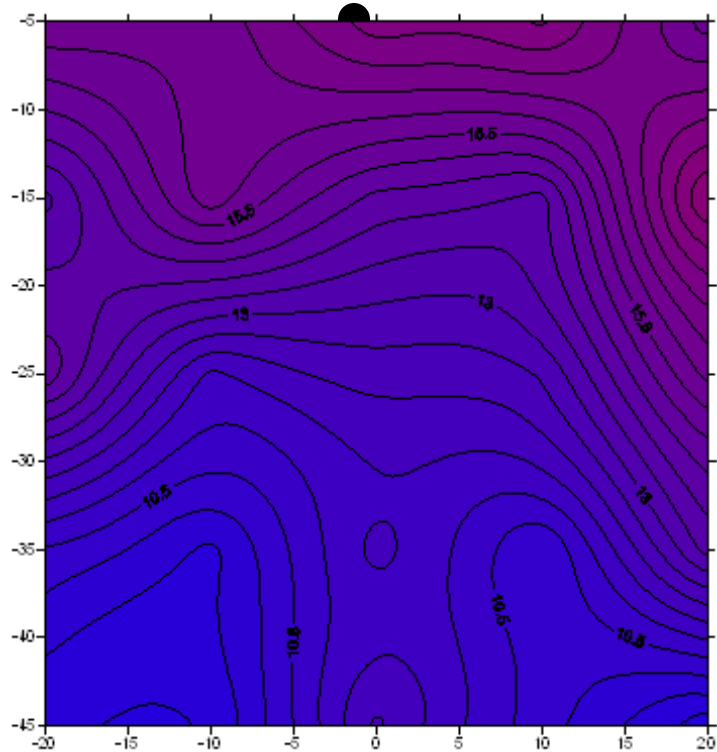
(Data from Scott Jones – Utah Univ.)

תוצאות דיגום קרקע

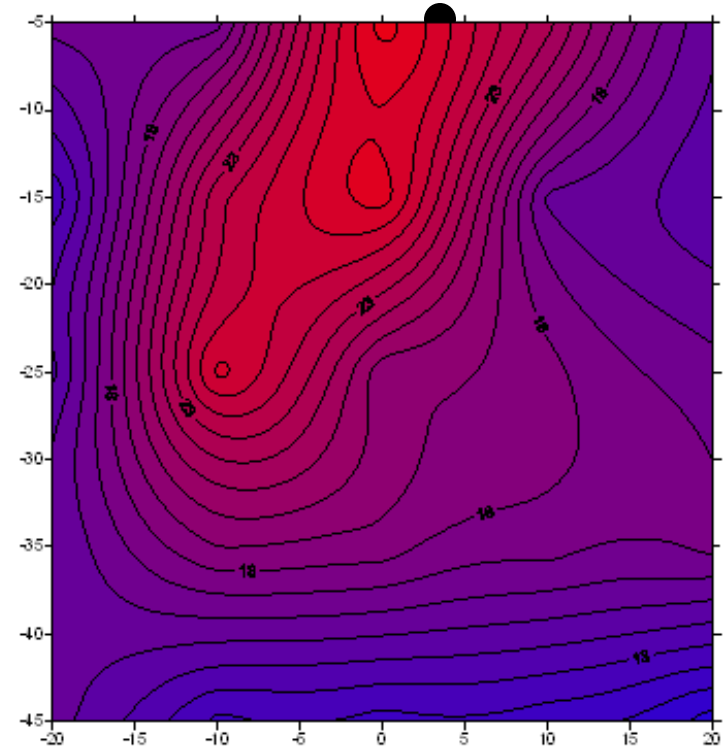


Organic matter accumulation below the dripper

FW

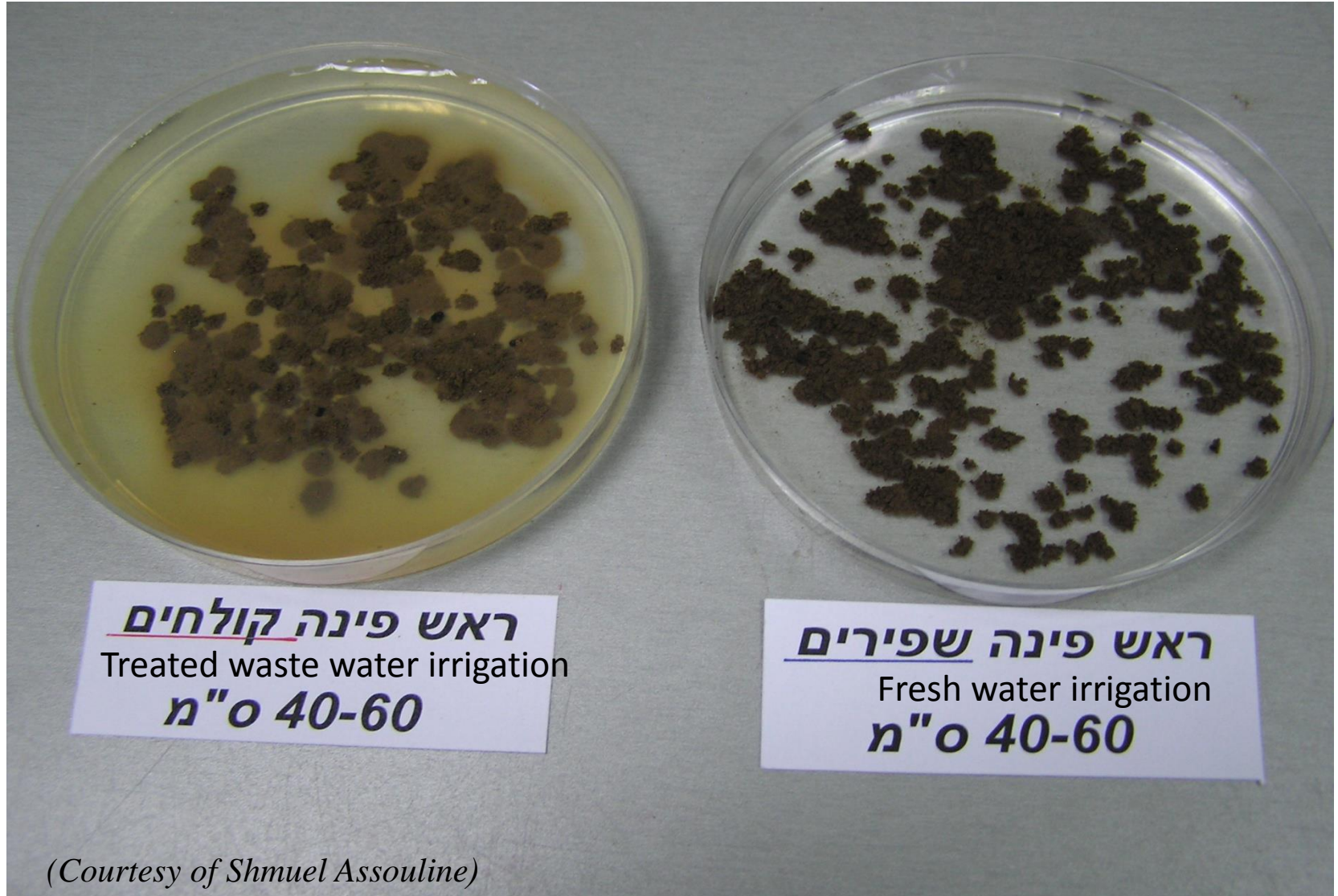


WW



(Courtesy of Shmuel Assouline)

Aggregate stability after 24 hours in water



Infiltration rate of soil in the root zone

**Soil after
Treated
Waste
water**

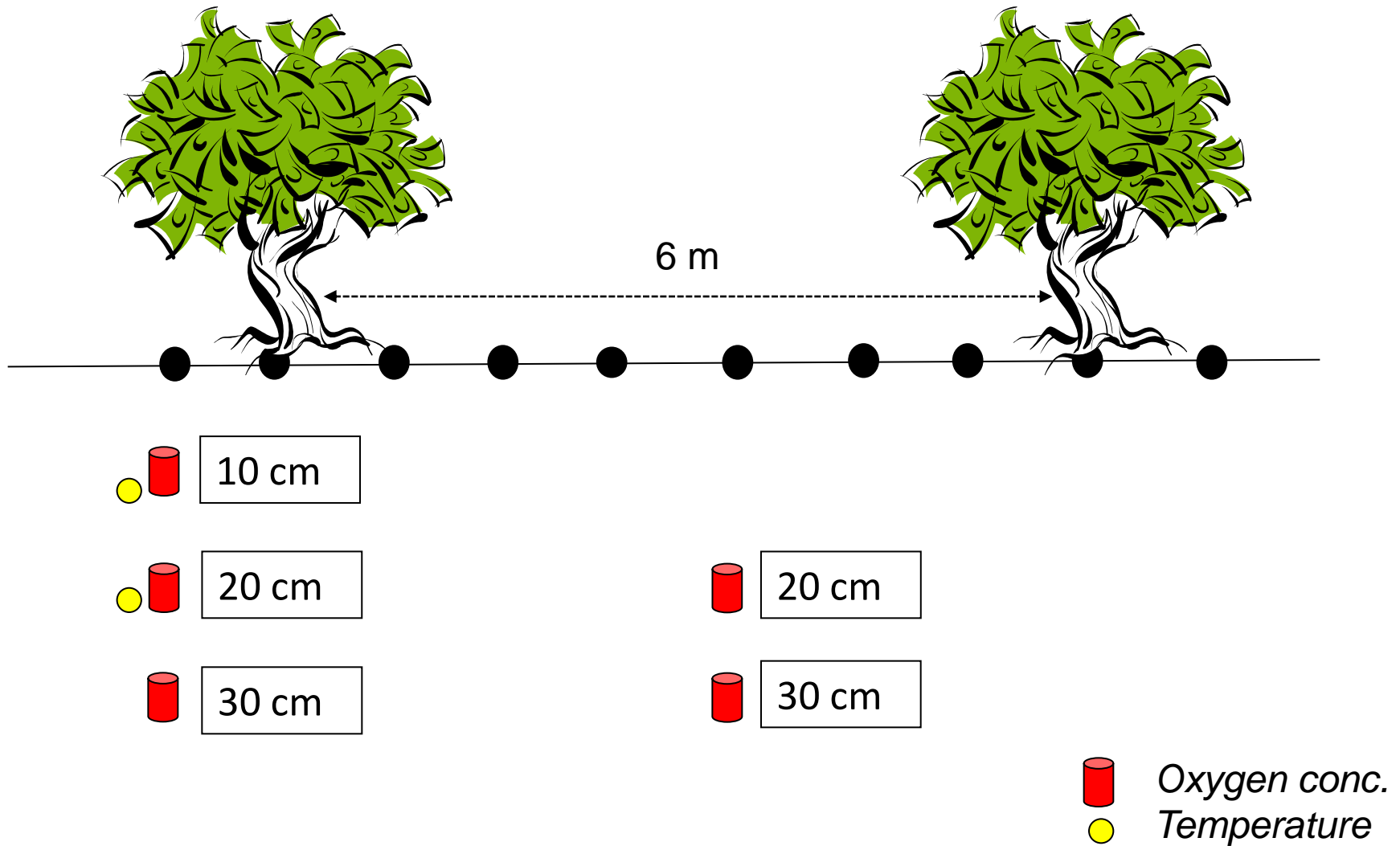
**Soil after
Fresh
water**



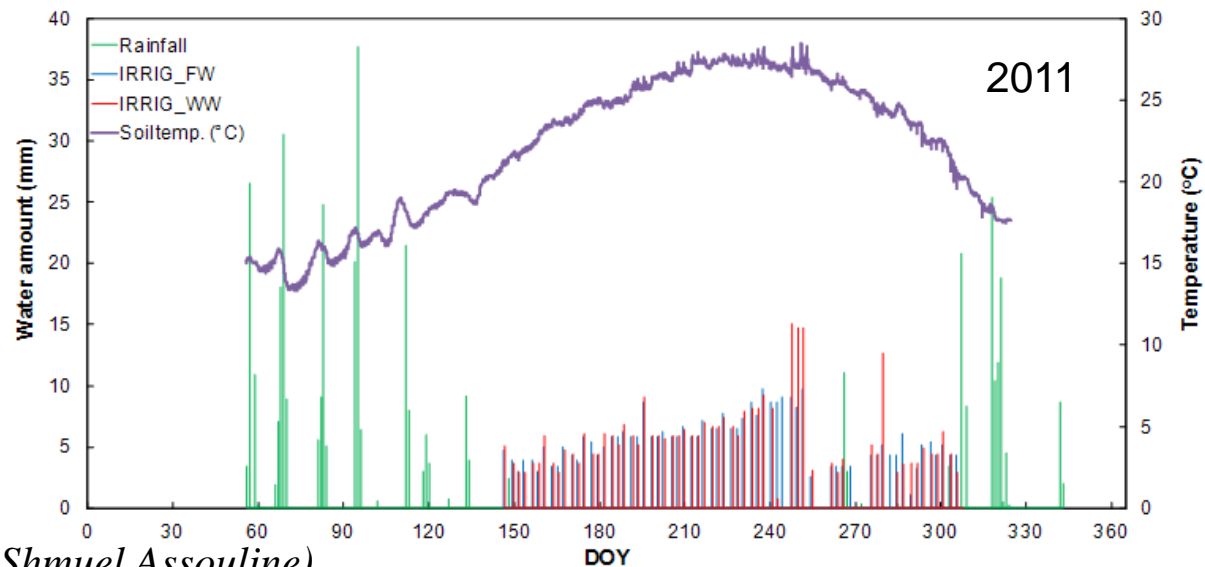
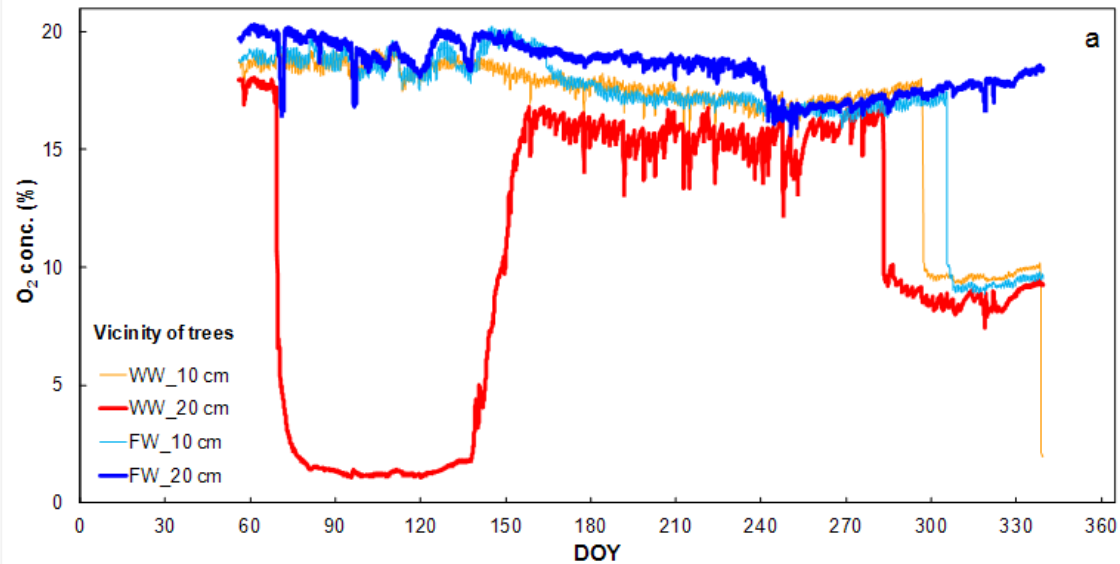
[Infil_Rosh_pina.wmv](#)

(Courtesy of Shmuel Assouline)

Monitoring changes in a range of soil physical properties in the field. These range from hydraulic conductivity of soil to evaporation rates and soil aeration and oxygen.

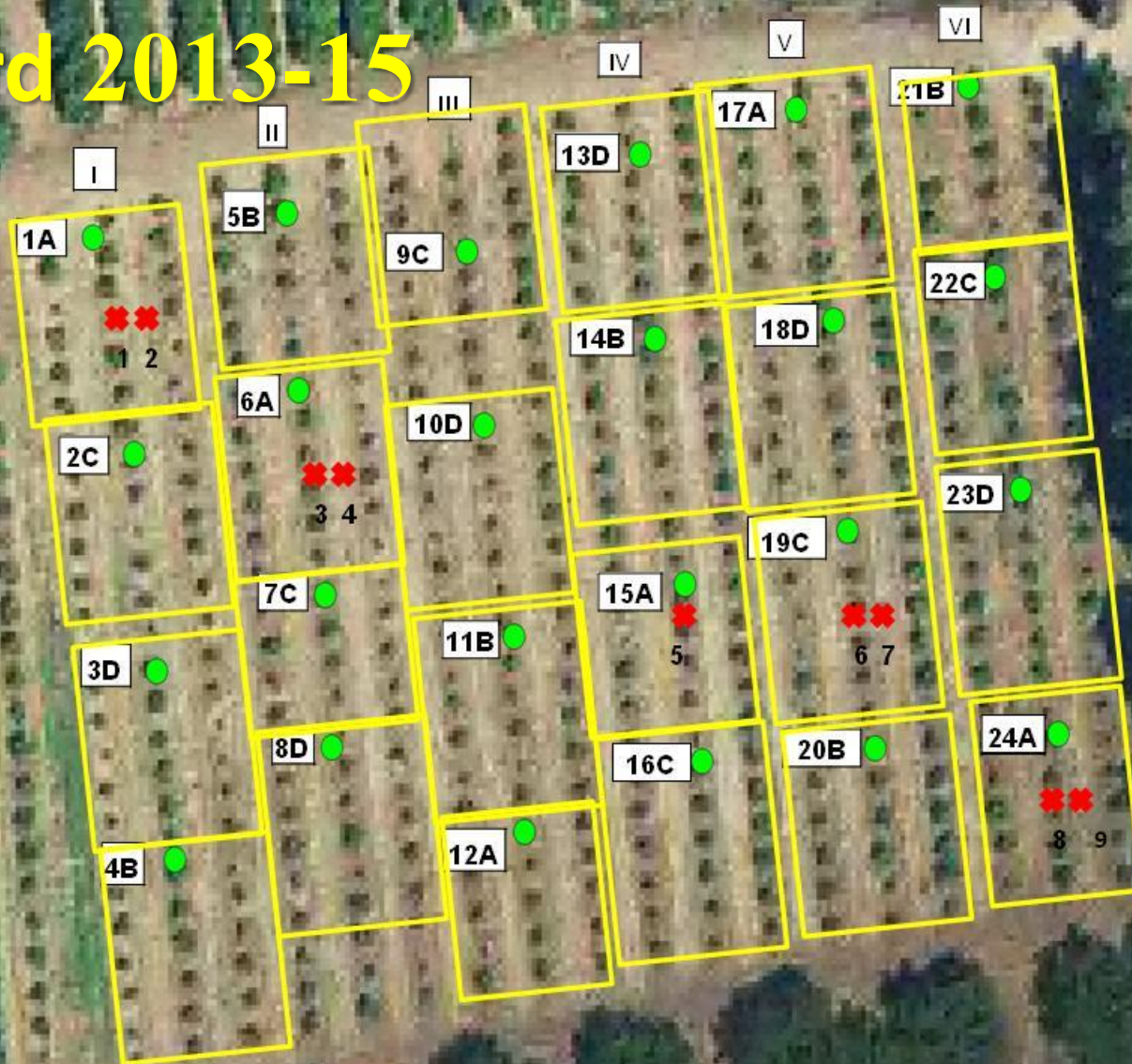


Seasonal changes in soil oxygen concentrations

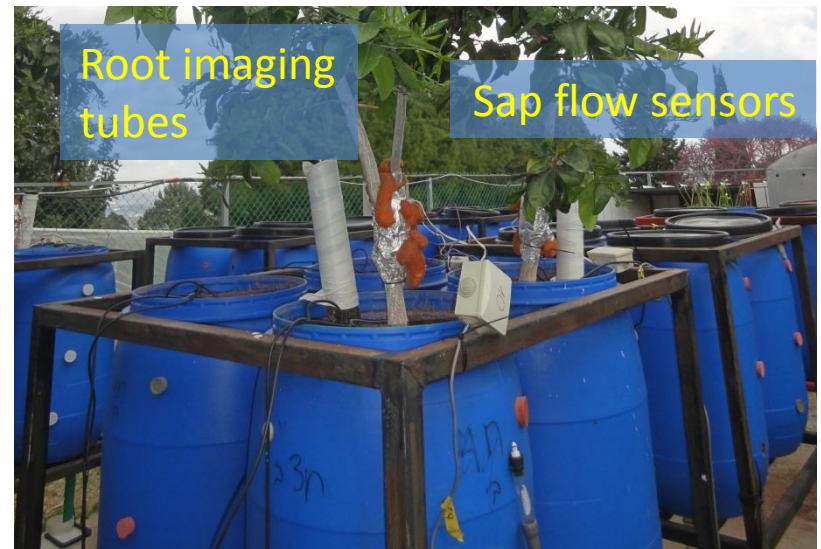
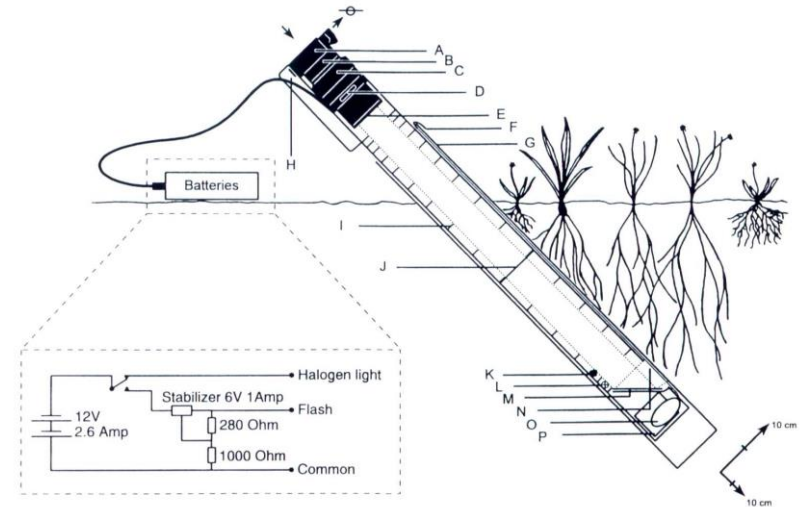


(Courtesy of Shmuel Assouline)

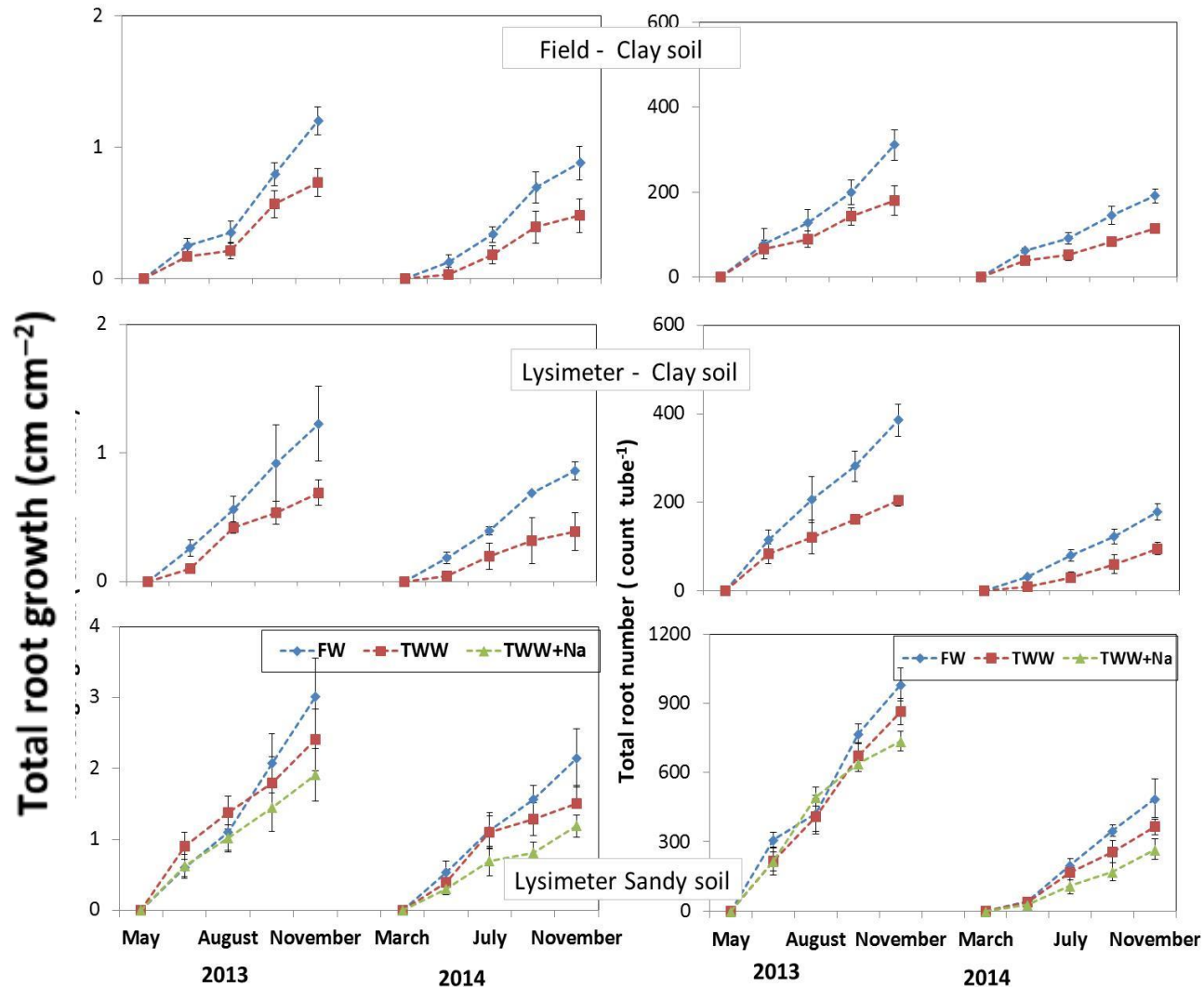
Experiment in Mizra Citrus Orchard 2013-15



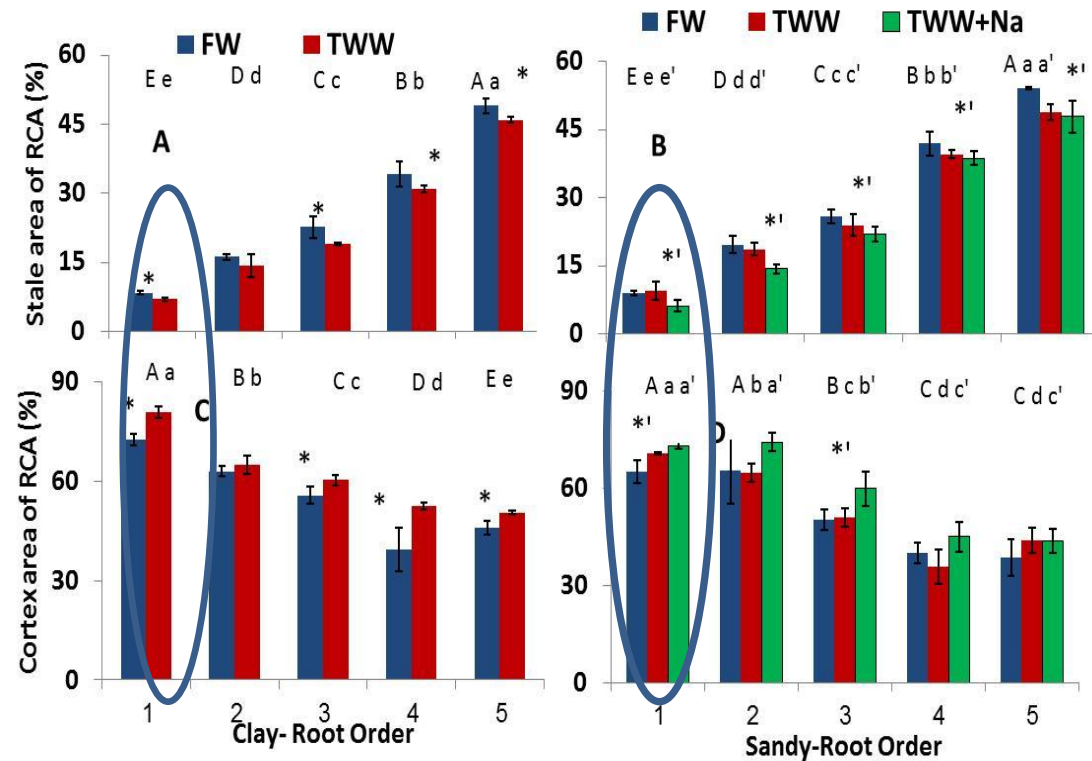
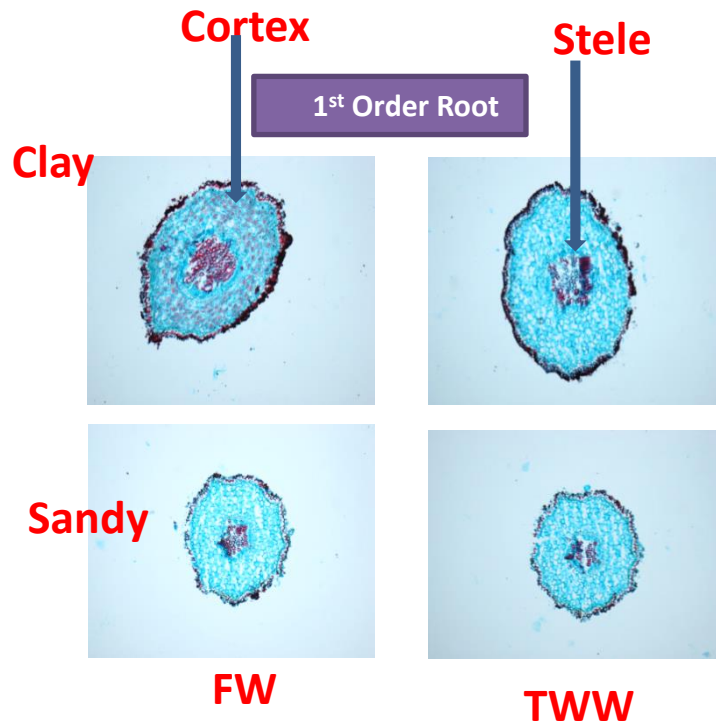
Lysimeter experiment at Technion, Haifa



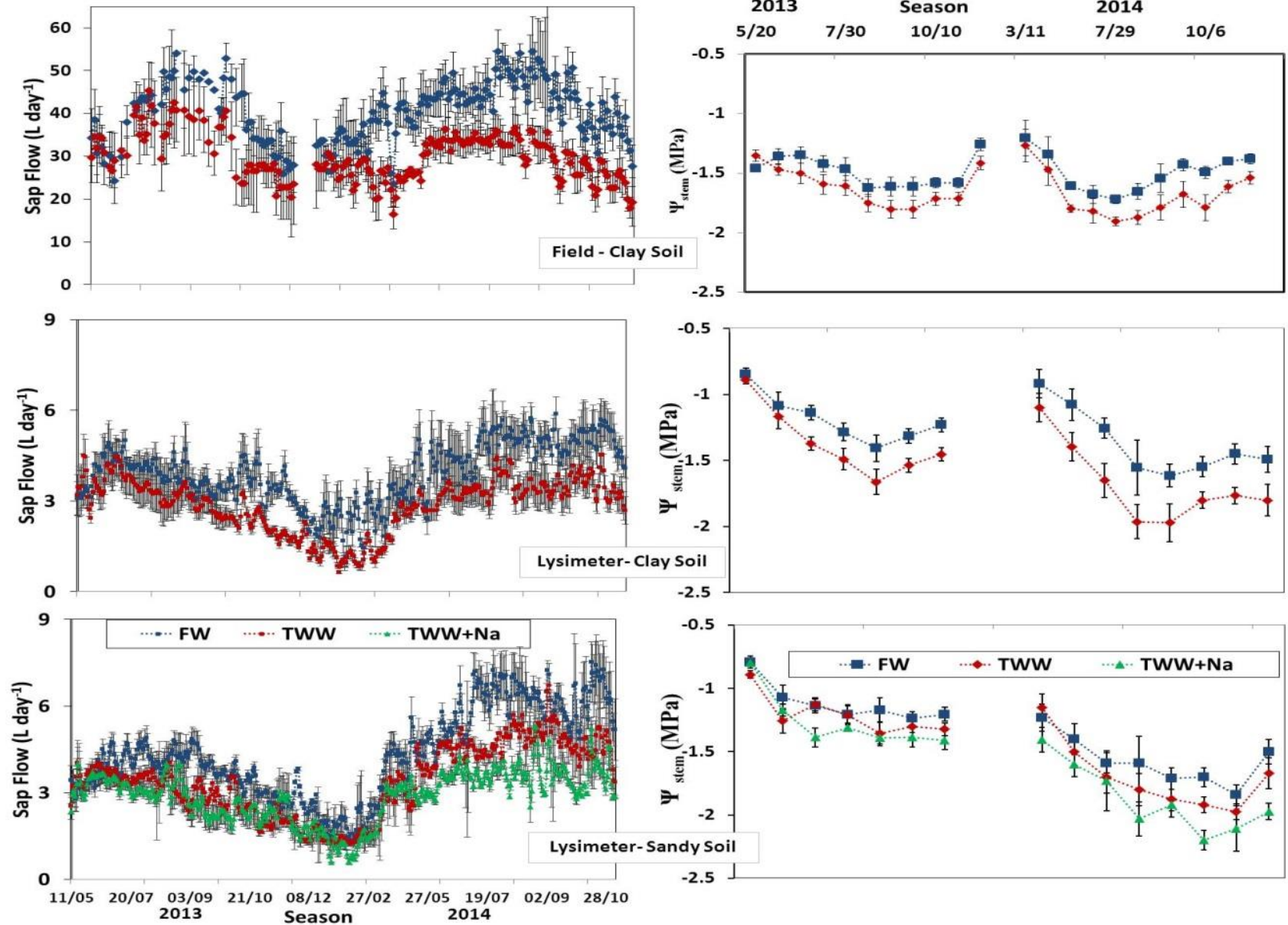
Root response to water quality



Root response to water quality in two soils



Results: Plant response to water quality



- **Conclusions:**
- **Treated waste water (TWW) is an important source of irrigation water in Israel. Currently 50% and in the future increasing in importance.**
- **TWW irrigation can be beneficial in reducing pollution and greenhouse gas emission, due to savings in fertilizers.**
- **TWW treatment and chemistry are critical for proper use.**
- **In sandy soil winter rains wash soils and proper long term use is not problematic.**
- **In clay soils long term TWW use leads to changes in soil structure and chemistry - salinization, increased sodification and organic matter accumulation in the root zone.**
- **This can result in reduced conductance and infiltration, and increased rate of evaporation. In the avocado, pear and citrus orchards studied the overall influence was detrimental to roots and soil properties.**
- **Current research is focusing on ways to solve these problems in clay soil.**



Thanks for your
attention

Thanks to my co-workers, colleagues and students:

**Shmuel Assouline, Asher Bar-Tal, Guy Levy, Meni Ben-Hur,
Indira Paudel, Victor Lukyanov...**