Changes of organic matter in soils irrigated with reclaimed wastewater

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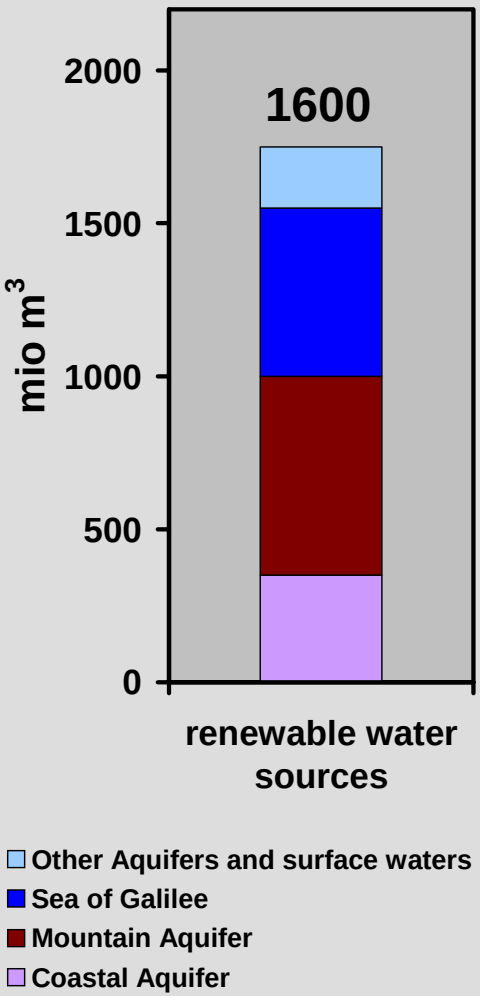
within the GLOWA Research Framework (BMBF & MOST)

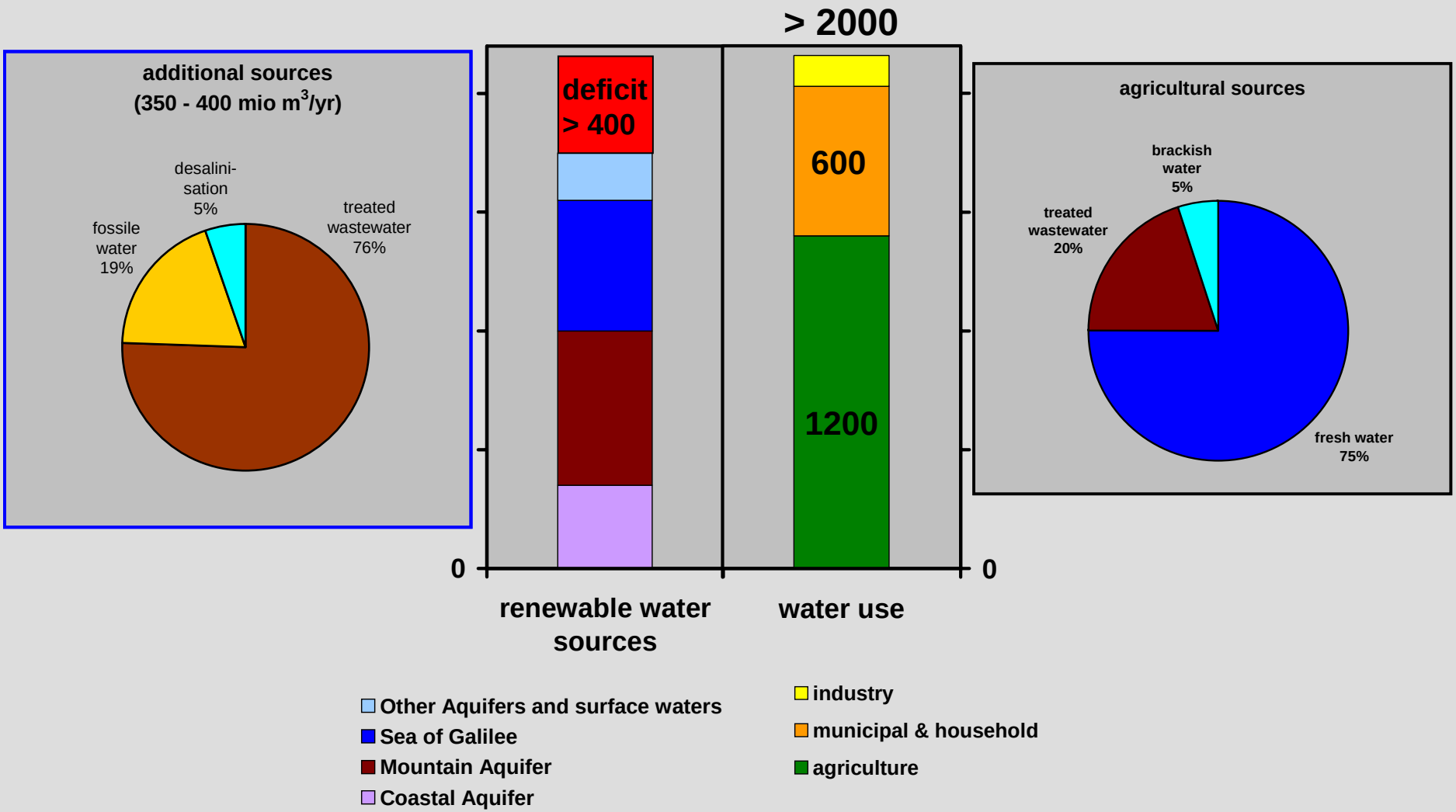
Background

- In many countries, water demand is expected to increase due to population growth and improved standard of living.
- Freshwater resources are limited, often overexploited or deteriorated due to pollution.
- Global climatic change may aggravate this situation by reducing precipitation and increasing evapotranspiration.
- "Clean" freshwater from ground- and surface waters will be preferentially allocated for use as drinking water and for certain industrial processes.
- For agricultural production, irrigation will therefore increasingly have to rely on marginal waters, such as saline waters or treated wastewater.

Water sources and water use in Israel



Water sources and water use in Israel



Problems associated with the use of reclaimed wastewater for irrigation

- Microbial pathogens (i.e. coliformes) may contaminate food crops.
- High nutrient loads (esp. N, P) increase the risk of groundwater eutrophication.
- Elevated salt loads can cause soil degradation and groundwater salinisation.
- Elevated inputs of heavy metals, organic pollutants, hormones and antibiotics may enter food chain or groundwater resources.
- Inputs of particulate and dissolved organic matter can affect mobility of contaminants and physical, chemical or biological soil properties.

Treated wastewater as irrigation water source (Ramat Hakovesh)

parameter	unit	effluent	freshwater
EC	dS/m	2.3	1.0
Cl	mg/L	364.0	201.0
Na	meq/L	21.4	4.3
Ca + Mg	meq/L	6.1	4.1
pH		8.3	7.4
DOC (Dissolved Organic Carbon)	mg/L	23.5	1.1
BOD (Biological Oxygen Demand)	mg/L	59.9 *	~ 1
COD (Chemical Oxygen Demand)	mg/L	234.0	~ 1

* present regulation for BOD in Israel 20 mg/L
proposed new regulation 10 mg/L

Methodological approach

1. Site screening (DOM quantity and quality)
2. Repeated sampling (DOM seasonality)
3. Laboratory experiments
   - soil respiration
   - substrate induced respiration (Priming)
   - microbial biomass (CFE)
   - microbial activities (FISH)
4. Soil organic matter inventories

Sampling sites for screening

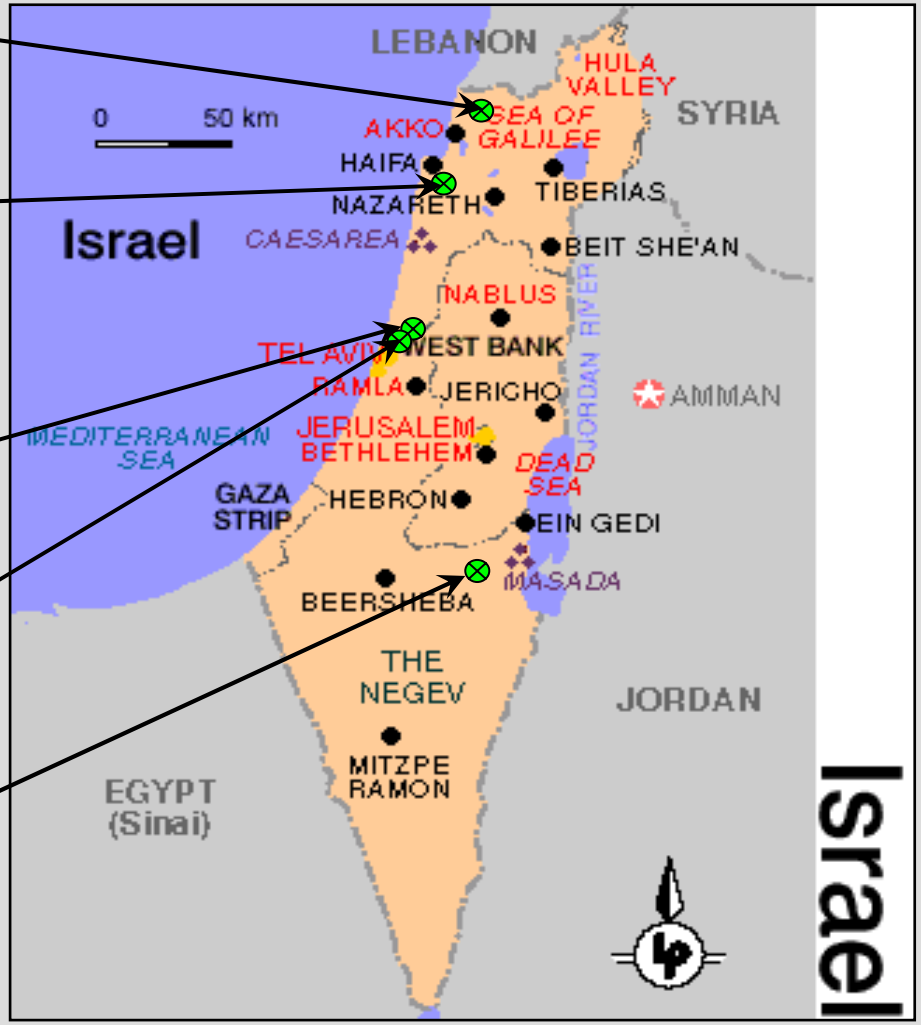
Gaaton

Yagur

Ramat Hakovesh

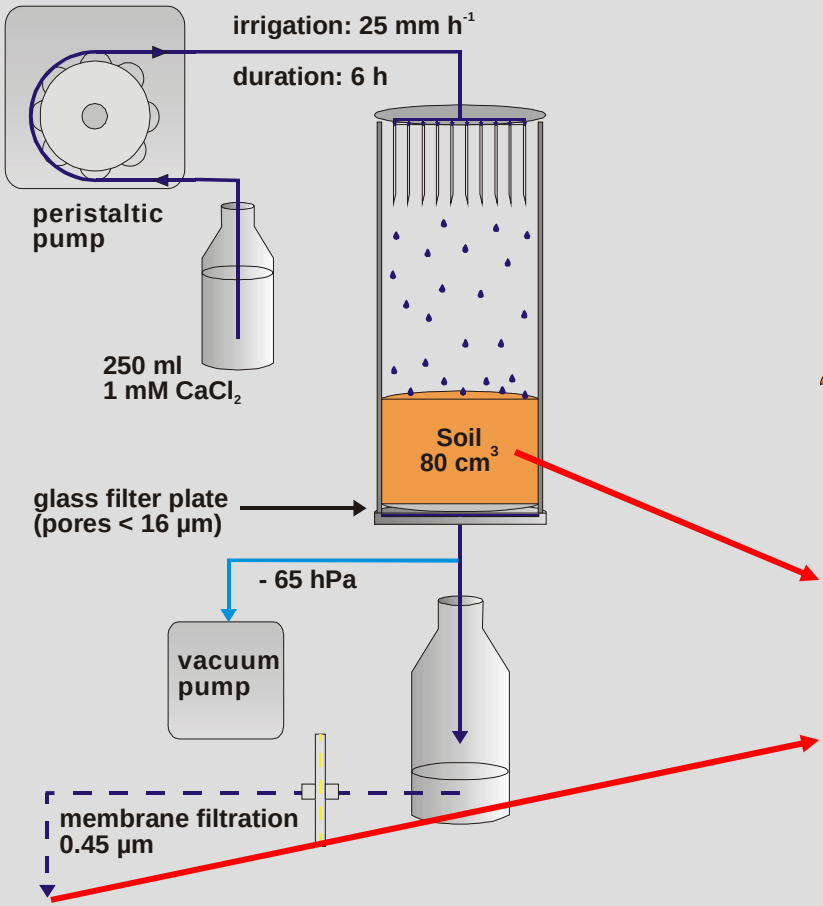
Basra

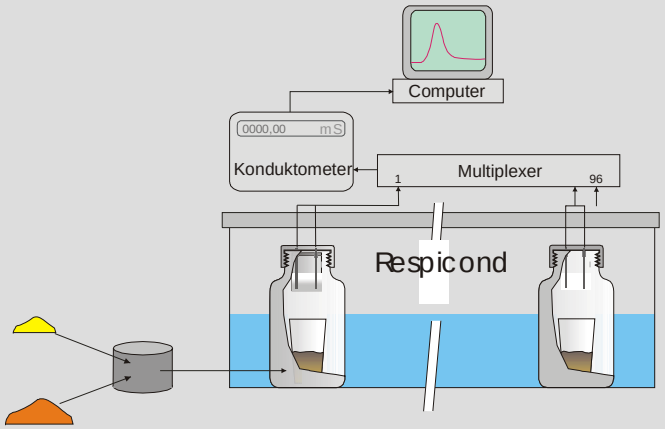
Arad



Percolation of soil samples

Incubation of soil samples (CO_2, $^{14}CO_2$, $^{13}CO_2$)

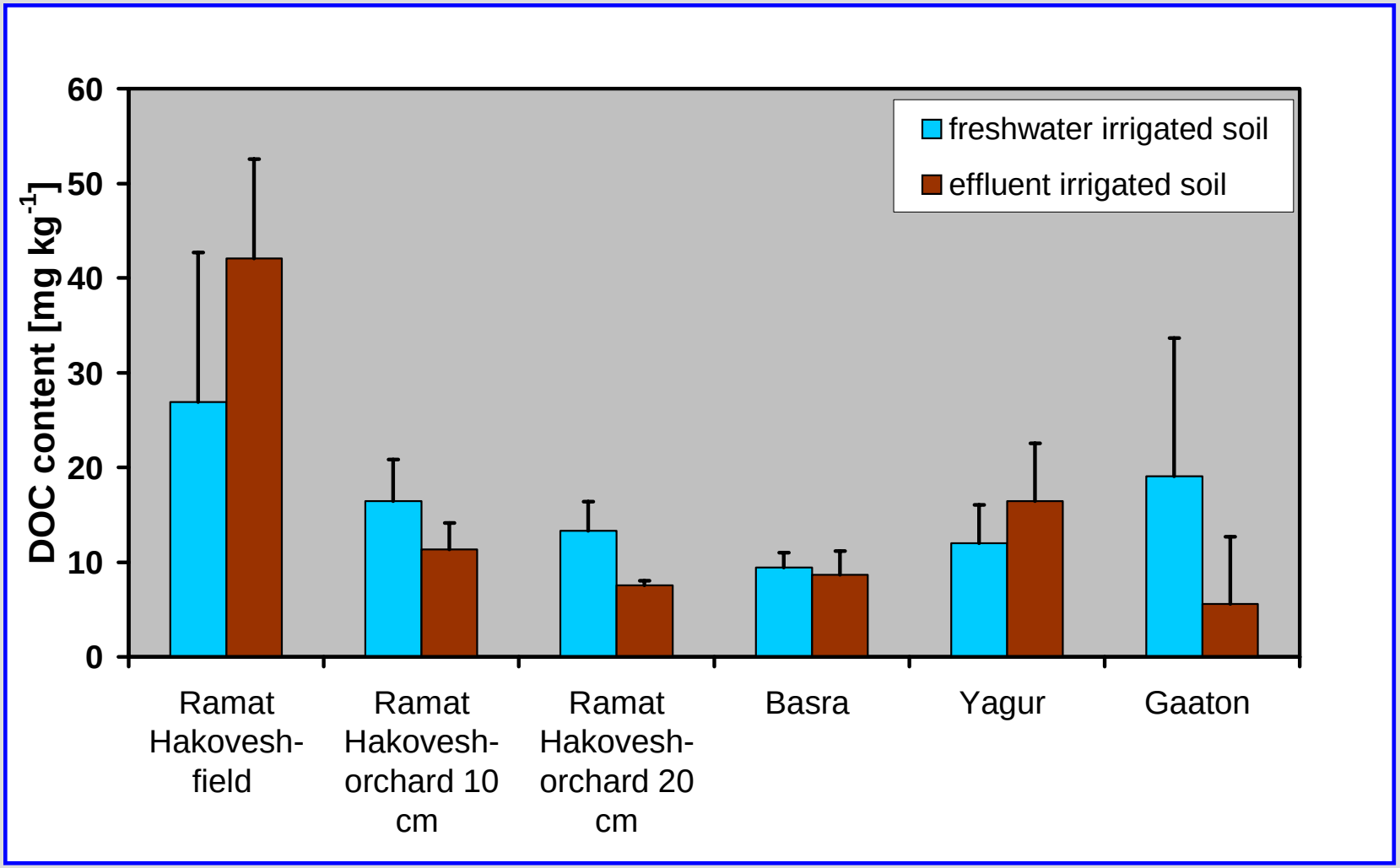




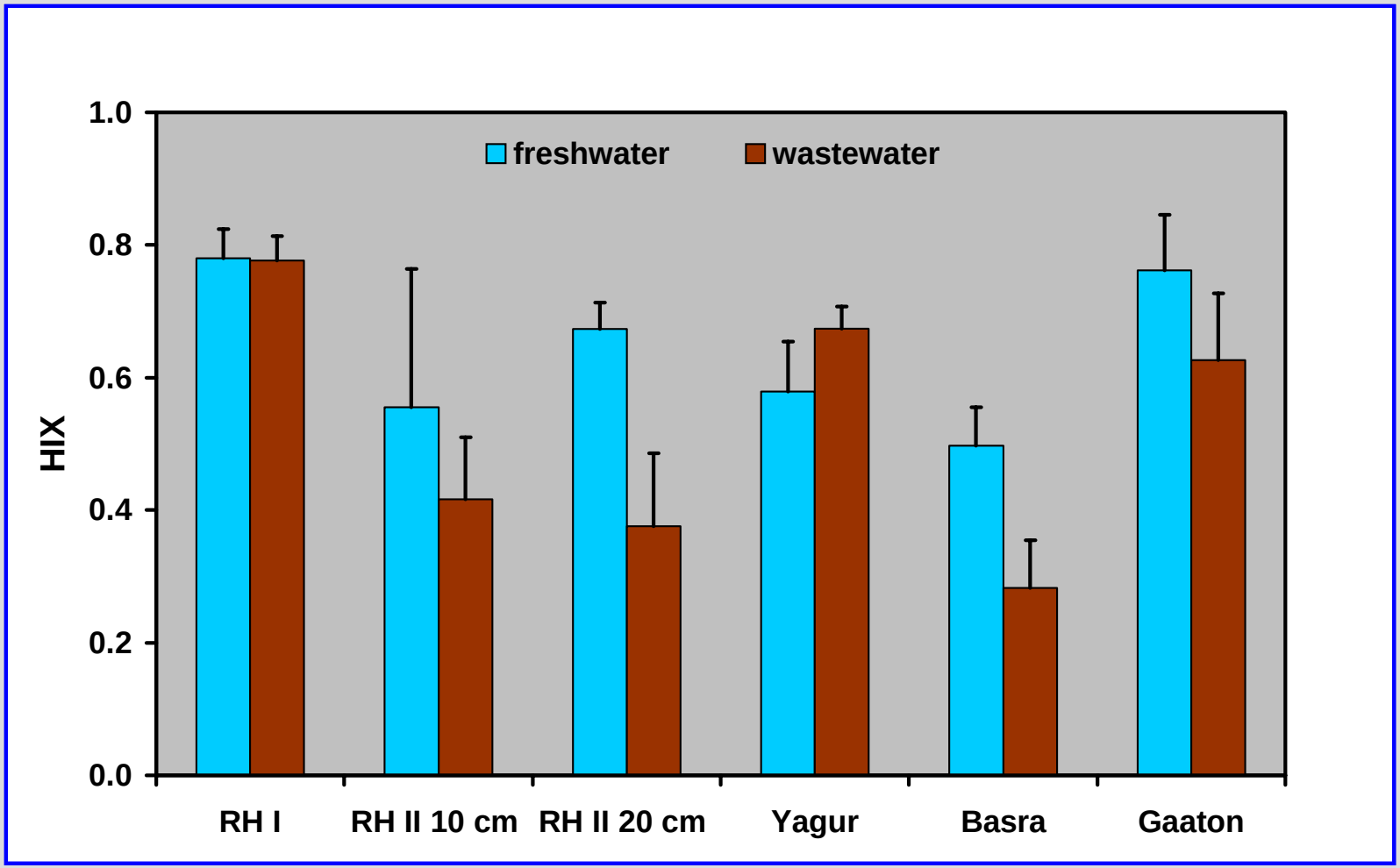
Texture, C_{org}, N_t, C_{mic}, $\delta^{13}C$

pH, EC, anions,
DOC, UV-absorbance, fluorescence,
biodegradability, XAD8-fractionation,
K_{DOC}, $\delta^{13}C$

Extractable DOC in the soils from the different study sites

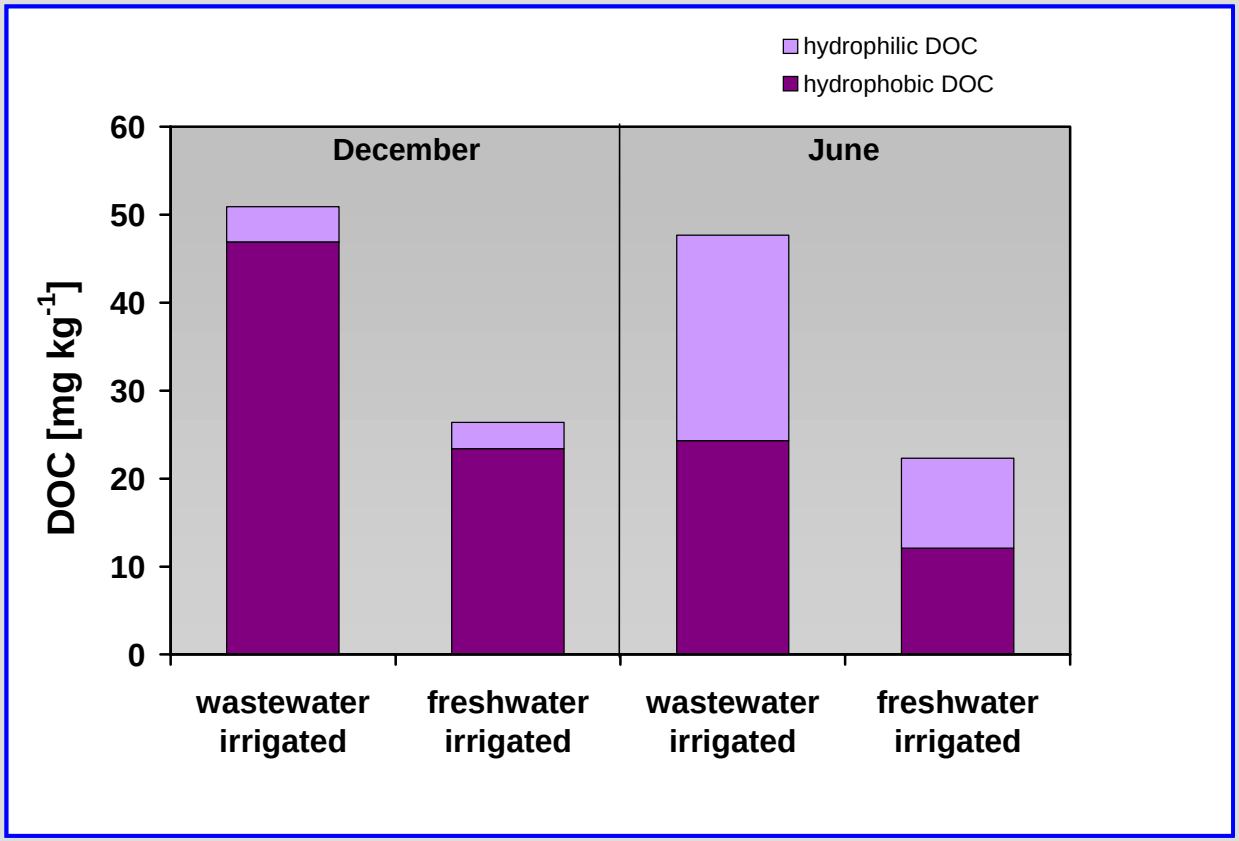


Humification Index (HIX) of extractable DOC in the soils from the different study sites



Seasonal differences in DOC properties

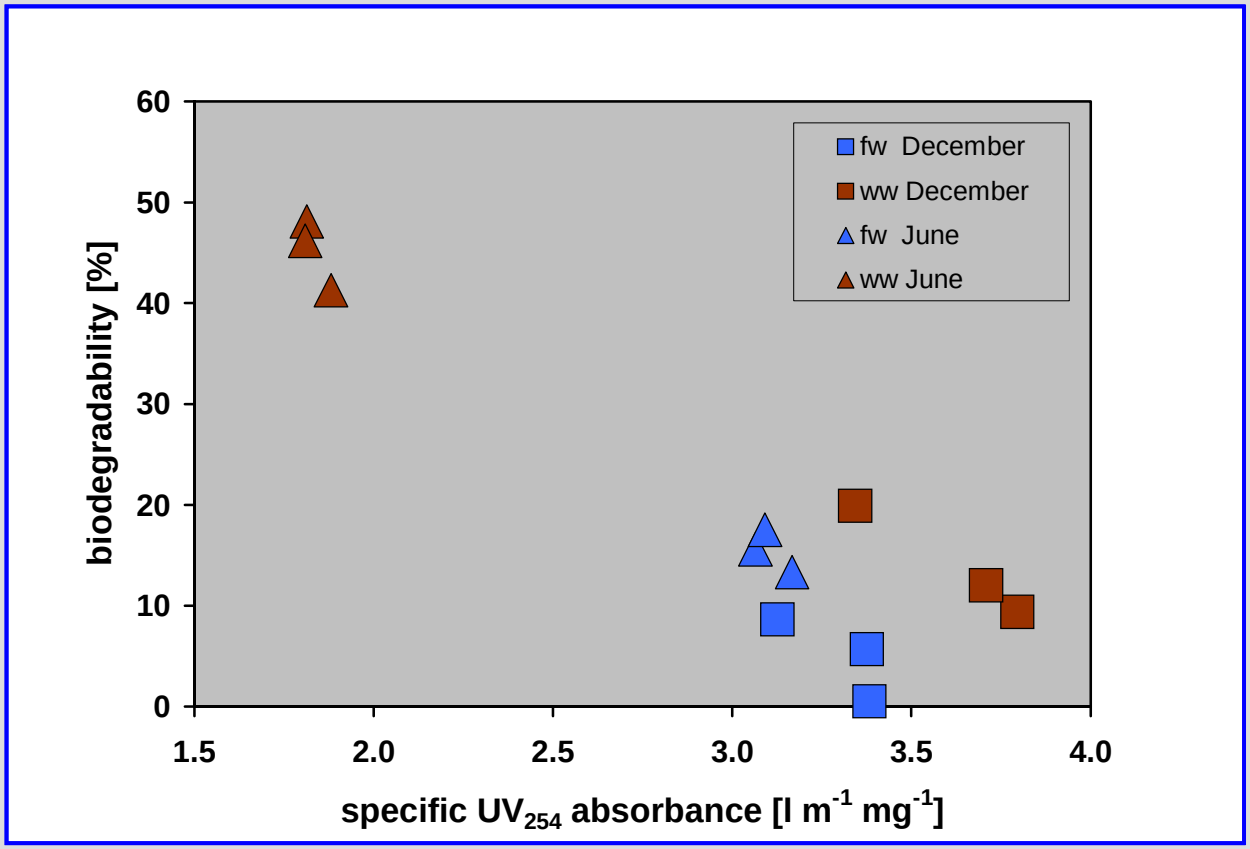
(Ramat Hakovesh field)



- ➔ **Consistently more DOC in wastewater irrigated soils**
- ➔ **Preferential release or production of hydrophilic DOC compounds during rainy season in both sites**

Biodegradability and specific UV absorbance

(Ramat Hakovesh field)



- ➔ **Easily degradable DOC compounds with lower SUVA are released during rainy season (Dec – May)**
- ➔ **Wastewater irrigation effects of previous year are more pronounced after rainy season (due to higher microbial activity?)**

Soil incubation studies

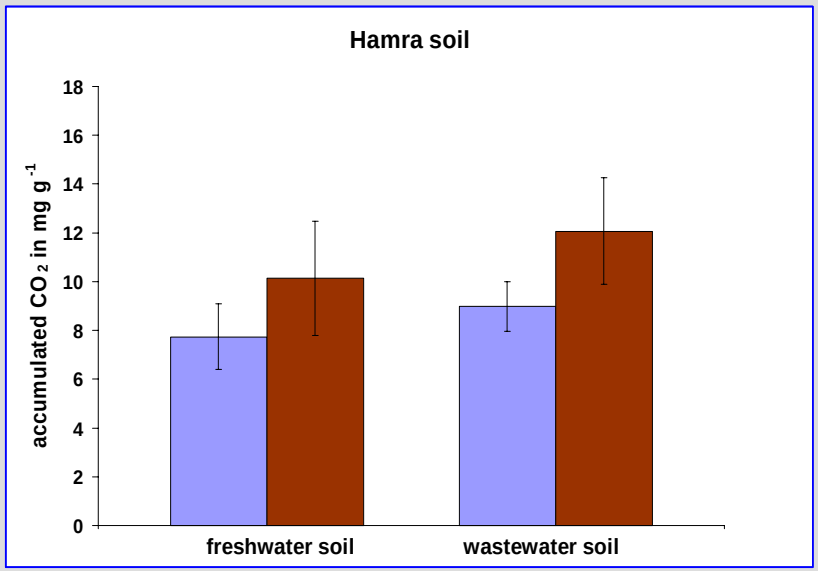
1. 4-month incubation of soil samples from two sites with fresh- and wastewater irrigated field plots, irrigated daily with fresh- or wastewater (factorial design).
   - monitoring of CO_2-evolution
   - microbial biomass
   - microbial cell counts (fluorescence in-situ hybridisation)
2. 4-week incubation of soil samples with substrate additions for the determination of priming effects
   (glucose, ^{14}C-fructose, ^{14}C-alanine)
   - CO_2, $^{14}CO_2$

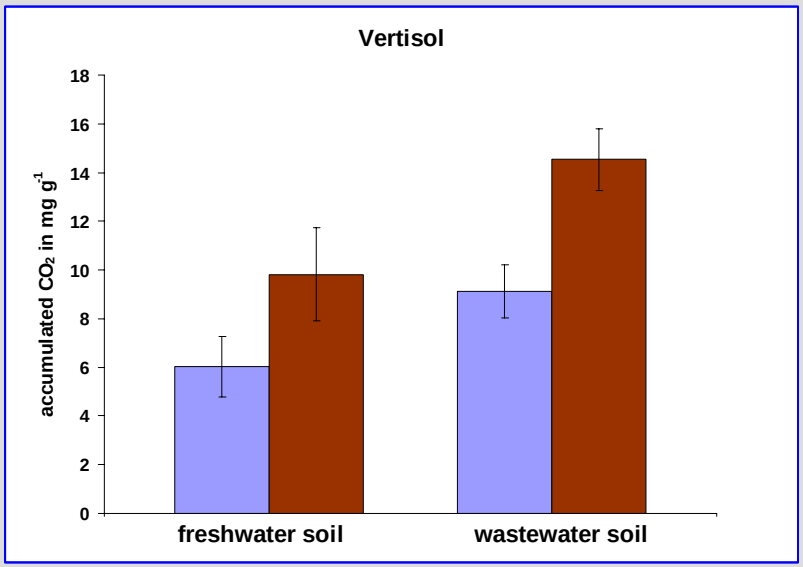
Soil respiration

CO_2 evolution accumulated in a 4 month irrigation experiment

fw irrigation

ww irrigation

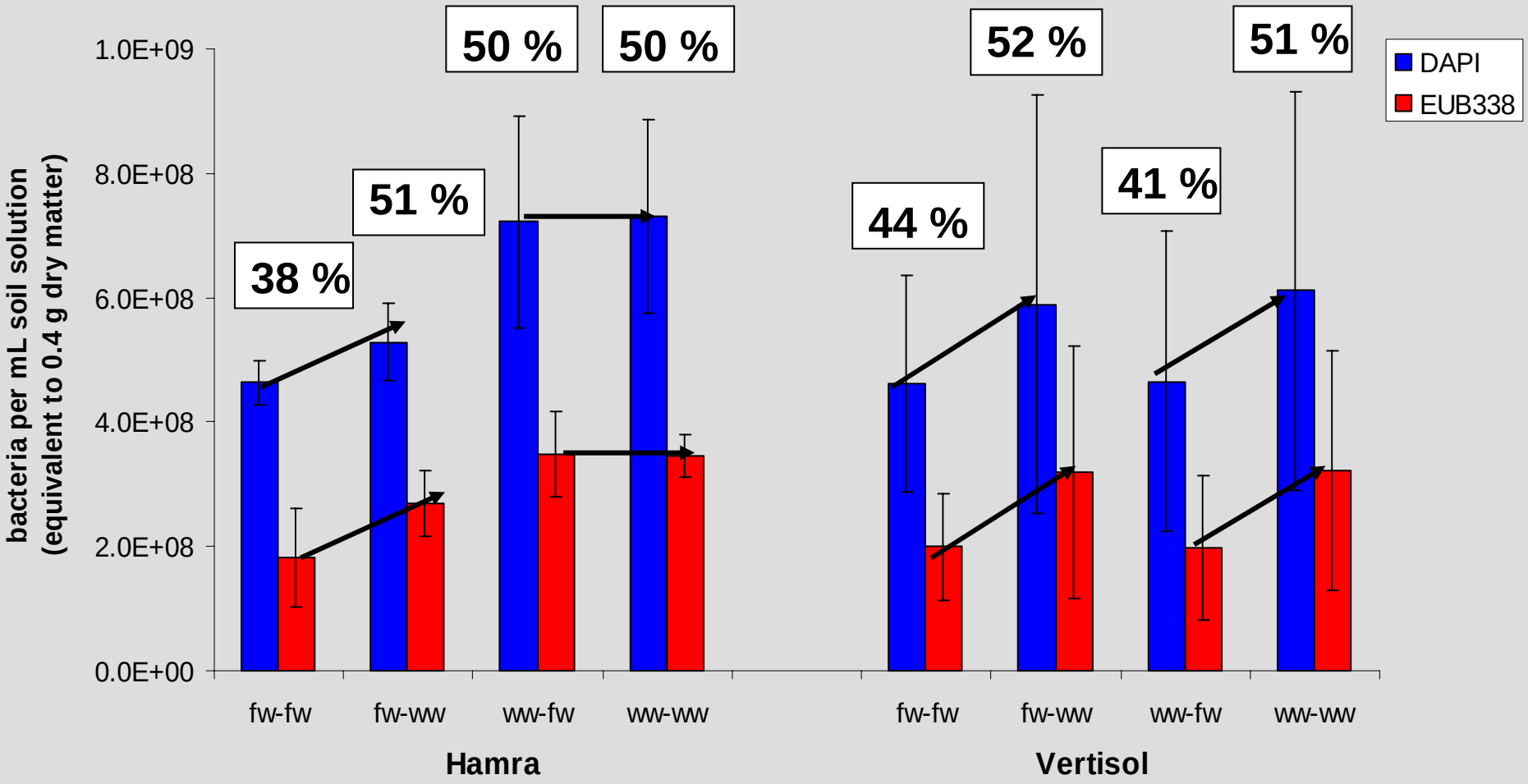




➔ microbial respiratory activity is higher in soils originating from wastewater irrigated sites

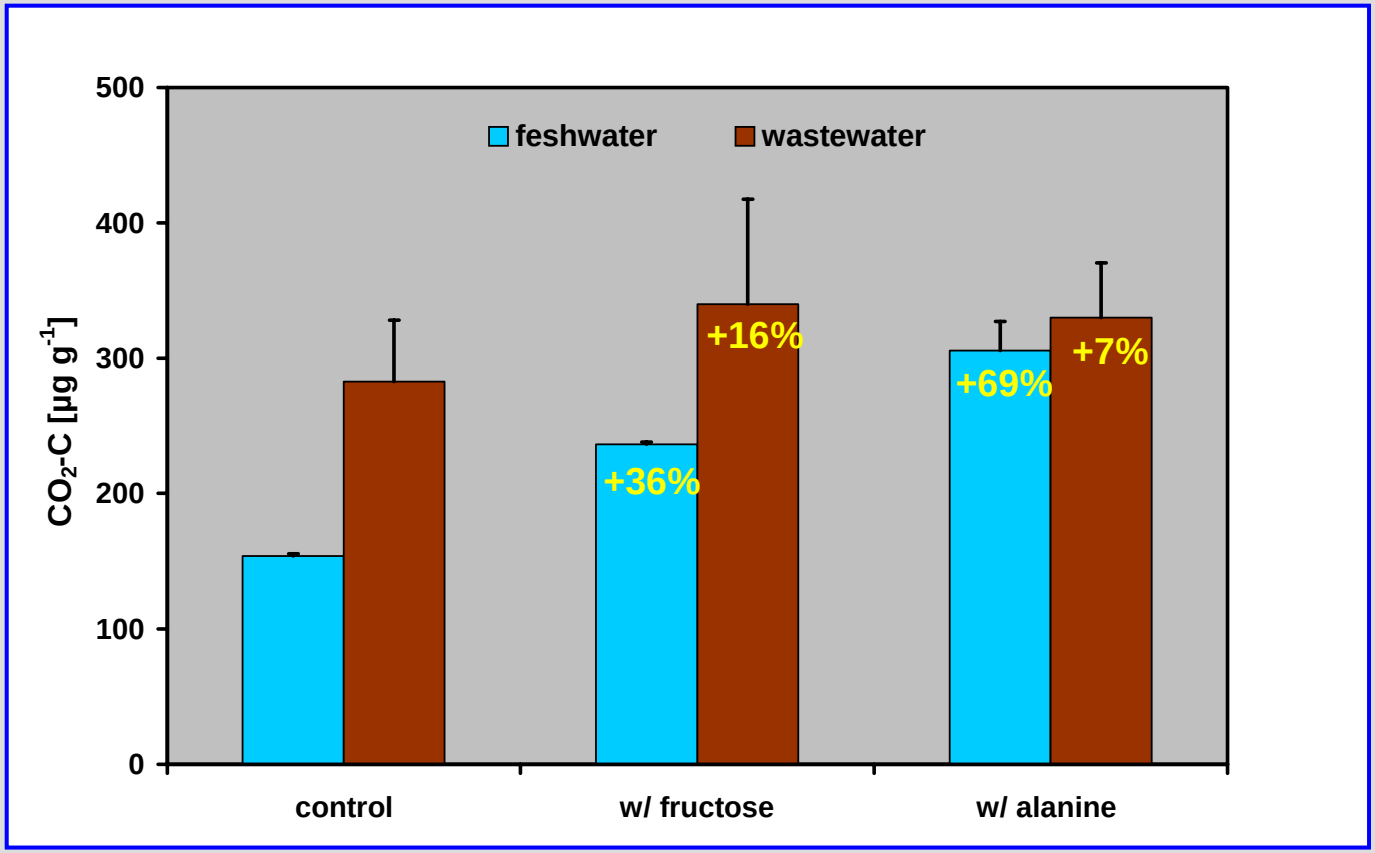
➔ Wastewater irrigation in the lab stimulates microbial activity in all soils

Bacterial counts
after 4 months of irrigation



Effects of substrate additions on soil respiration

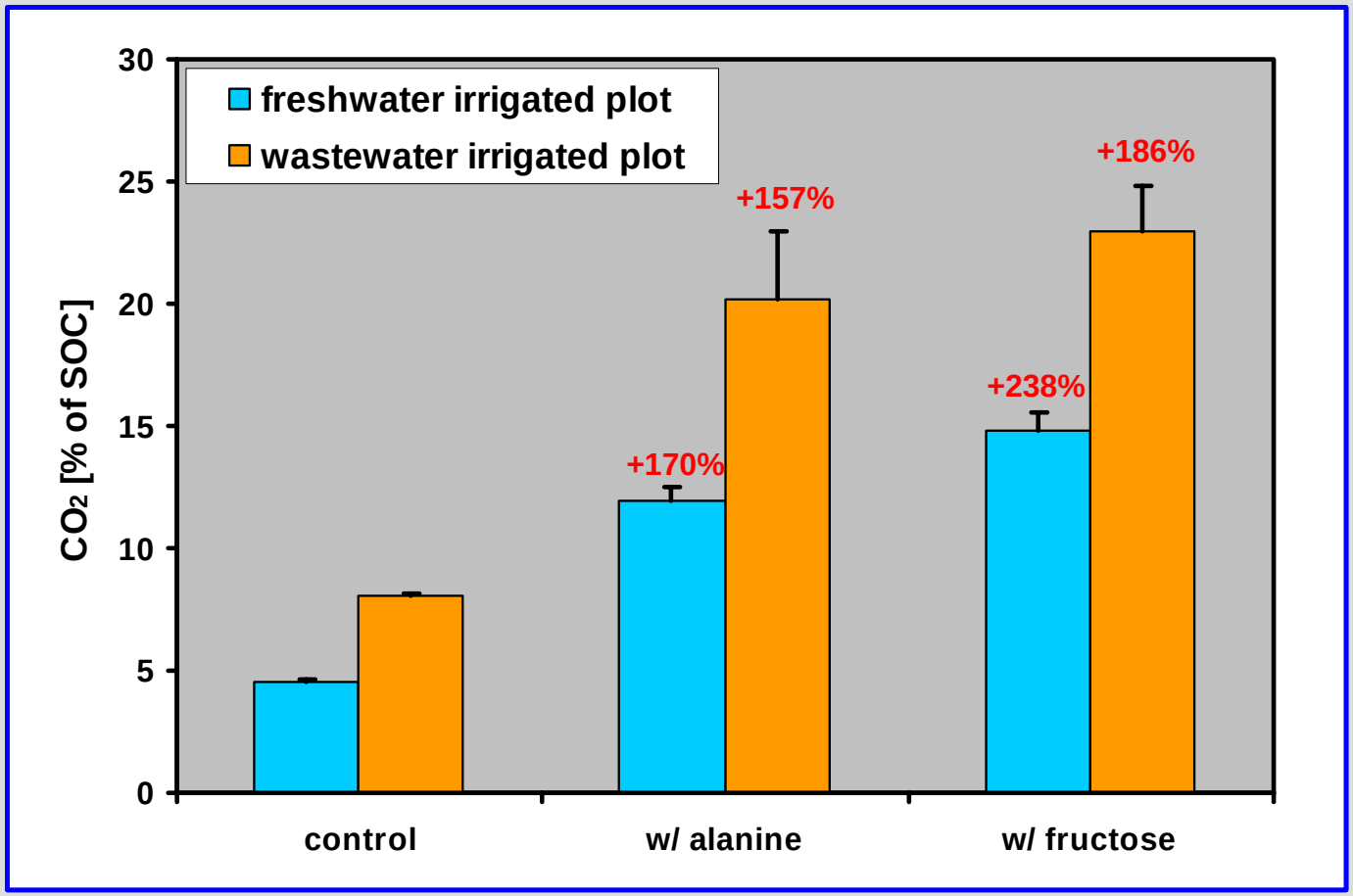
(Ramat Hakovesh orchard, 10-20 cm)



- ➔ Elevated CO_2-release from wastewater irrigated soil can not be attributed to higher C_{org} content
- ➔ Microbial activity in the freshwater irrigated soil is limited by the availability of easily degradable substrates

Priming effects after substrate additions

HaMapil (90-100 cm)

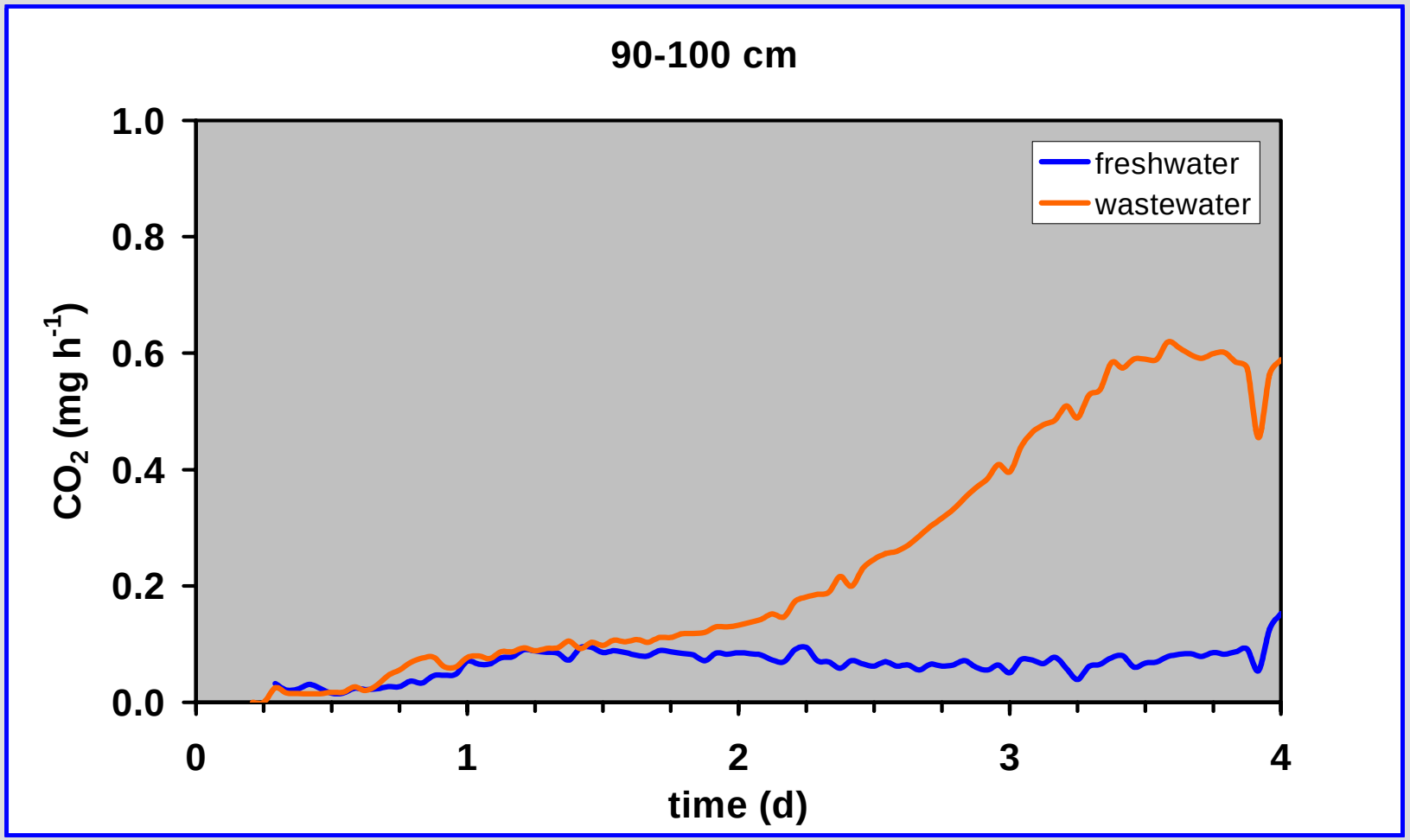


➔ Microbial activity in the subsoil is highly C-substrate limited

➔ Microbial activity is higher under effluent irrigation, but more stimulated by substrates under freshwater irrigation

Soil respiration after glucose addition (SIR)

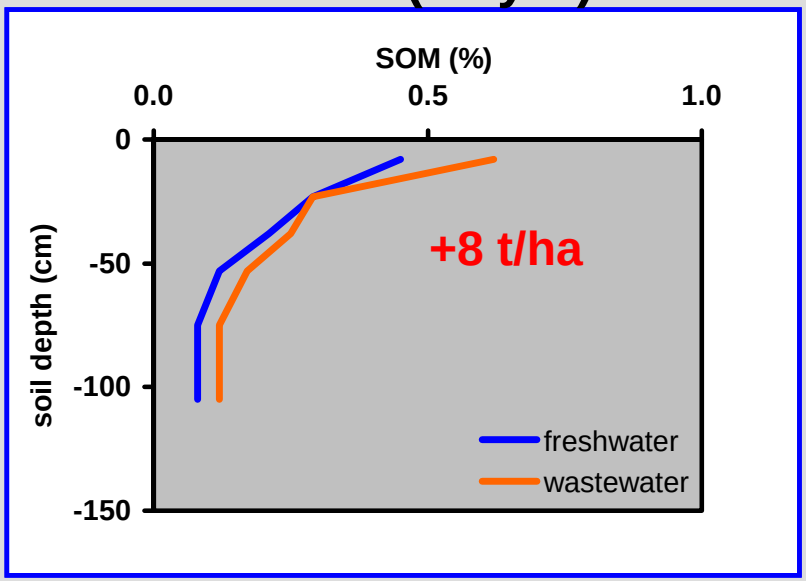
HaMapil



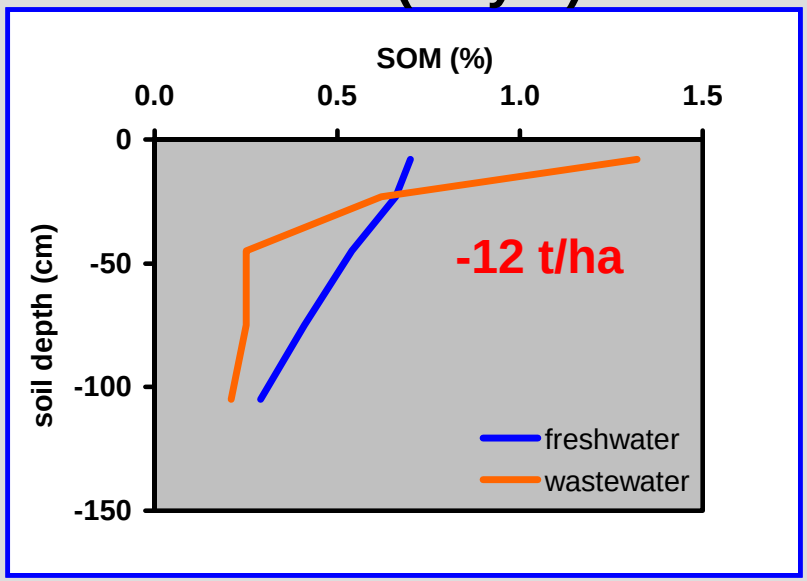
➔ Stimulation of microbial respiration by glucose is more rapid and stronger in the wastewater than in the freshwater irrigated soil.

Soil organic matter inventories

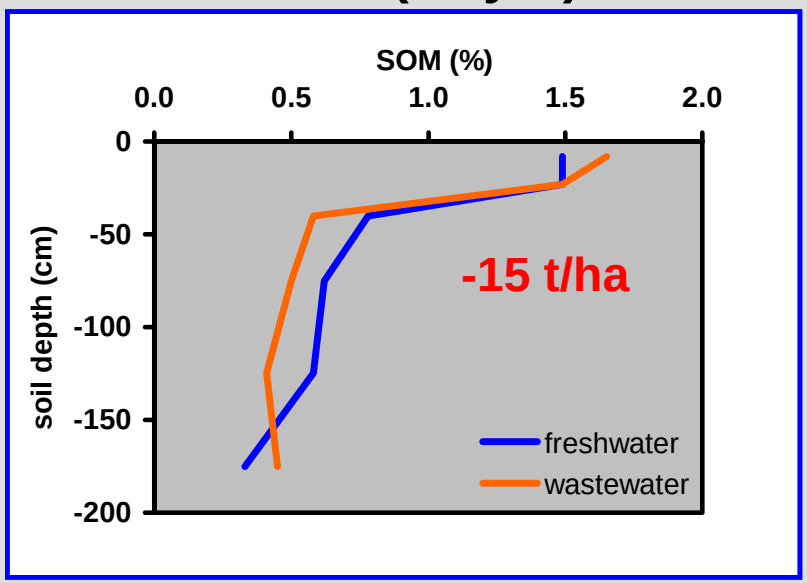
Arad (10 yrs)



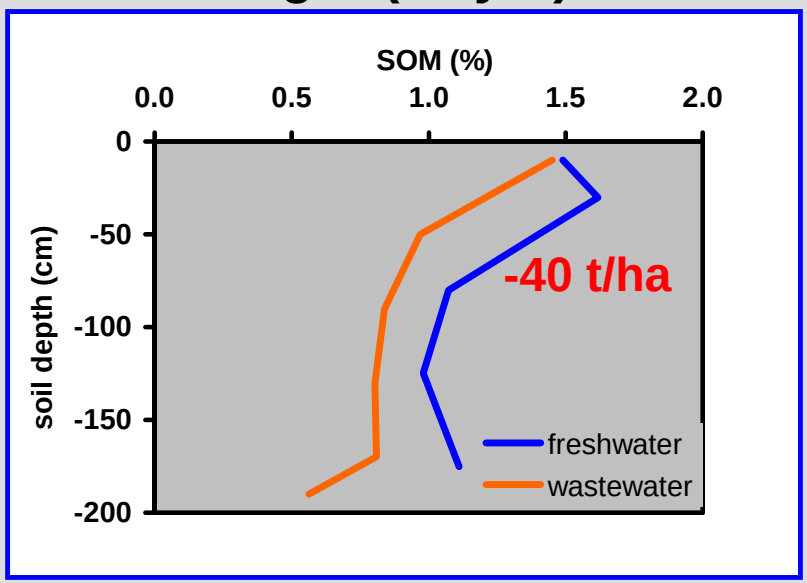
Basra (30 yrs)



Misra (12 yrs)



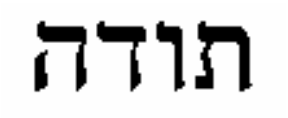
Yagur (35 yrs)



Summary and conclusions

- Wastewater irrigation has no consistent effects on the quantity or quality of DOC (or SOC) in topsoils.
- Microbial activity and SOM mineralization are stimulated by the application of wastewater.
- Microorganisms in wastewater irrigated soils are more adapted to the rapid mineralization of easily degradable substrates, but priming effects are more pronounced in soils from freshwater irrigated sites.
- In subsoils, wastewater irrigation can stimulate microbial activity to such an extent, that SOM is mineralized at a higher rate than it is replenished from organic inputs with wastewater.
- This is attributed to the inputs of easily degradable dissolved organic compounds with the wastewater.
- Possibly, leaching of degradation products of particulate wastewater-borne OM also contribute to such priming effects.
- A depletion of soil OM pools at a rate of >1 t ha^{-1} annually may have long-term effects on soil fertility and is a source of CO_2 to the atmosphere.

Thank you



Dankeschön

Relevance of the results for the planned research activities

- Priming effects seem to be ubiquous in soils that receive regular inputs of easily degradable organic compounds (such as manures). With our experimental approach, this can be detected at an early stage and thus may help to prevent long-term detrimental changes in soil properties.

- Soluble organic compounds have important ecological functions such as substrates for microbial activity or carriers for pollutants.

- DOC amounts and properties are easily determined and together with data on soil microbial activity are sensitive parameters and powerful tools for the detection of soil quality changes.

Conclusion

- Both soil types are effected differently by effluent irrigation
- Bacterial activity is increased through effluent irrigation
- Hamra: increase of activity with irrigation duration in effluent irrigated soil

  Vertisol: irrigation duration has no obvious effect on the activity of bacteria in effluent irrigated soil

- The strongest increase in activity could be determined in effluent irrigated soil under effluent irrigation

  - Microorganisms are already adapted to the compounds of the effluent water as substrate and develop better after irrigation break during winter

...

Conclusion

...

- direct and indirect methods for determination of activity of the soil bacteria correlate and a shift to an increase of activity can be seen

- effluent irrigated soil in the field experiment appeared to have clearly higher activity and the activity declined with depth

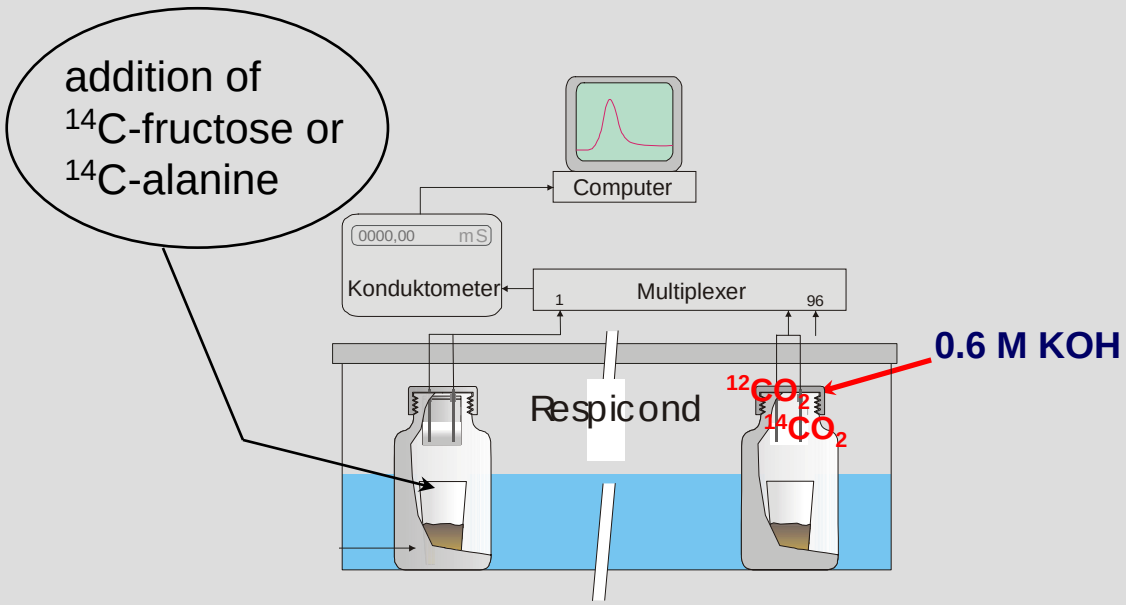
- freshwater irrigated soil showed no higher bacterial activity and no effects in depth

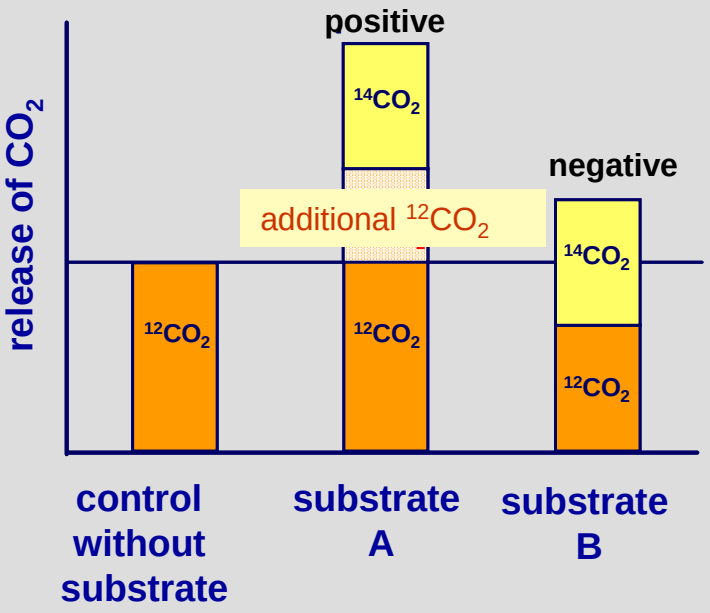
Treated wastewater used as irrigation water causes a lasting change of bacterial activity in soils. This depends on the soil type as well as on the irrigation duration.

To slide 5 (priming effects)

Priming-Effects are ...

... stimulation or inhibition of transformation and utilisation of SOM after addition of organic substrates

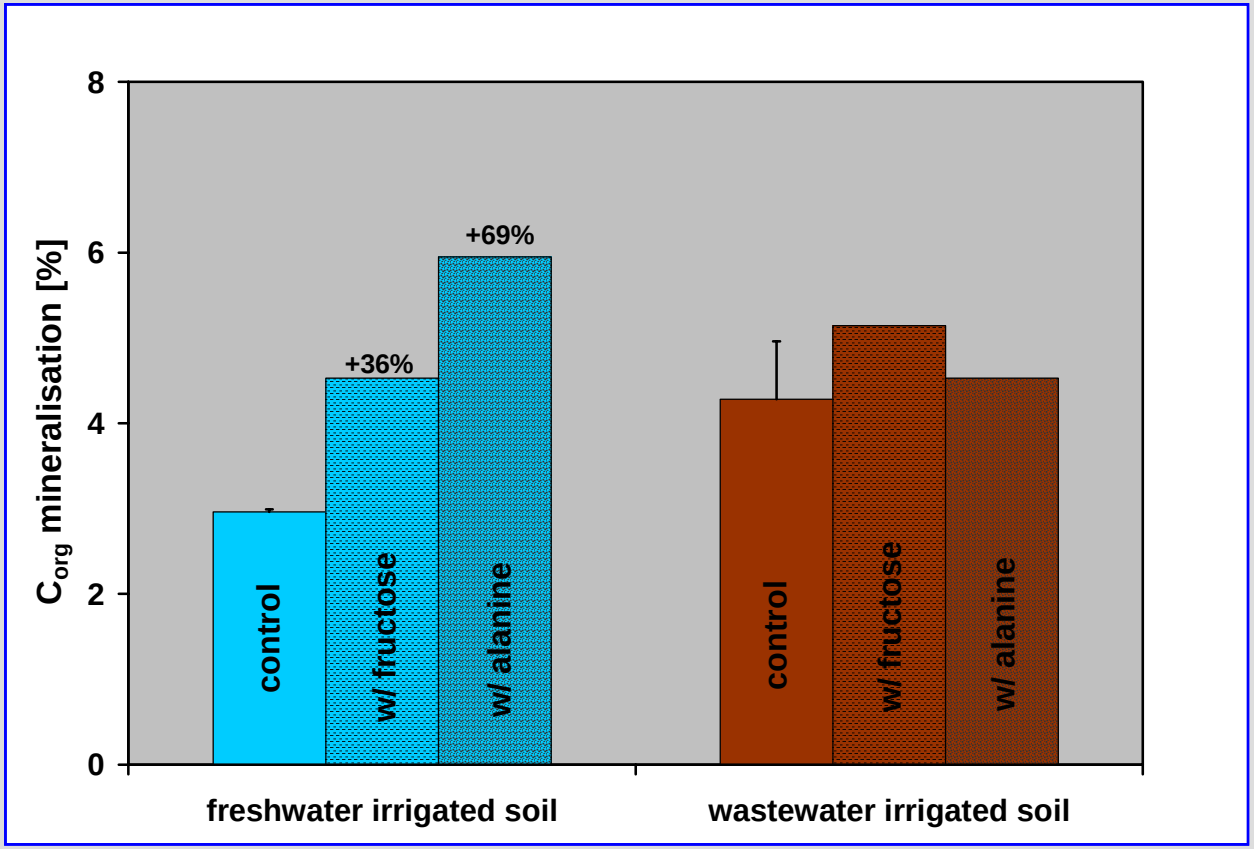




measurement of CO_2 release

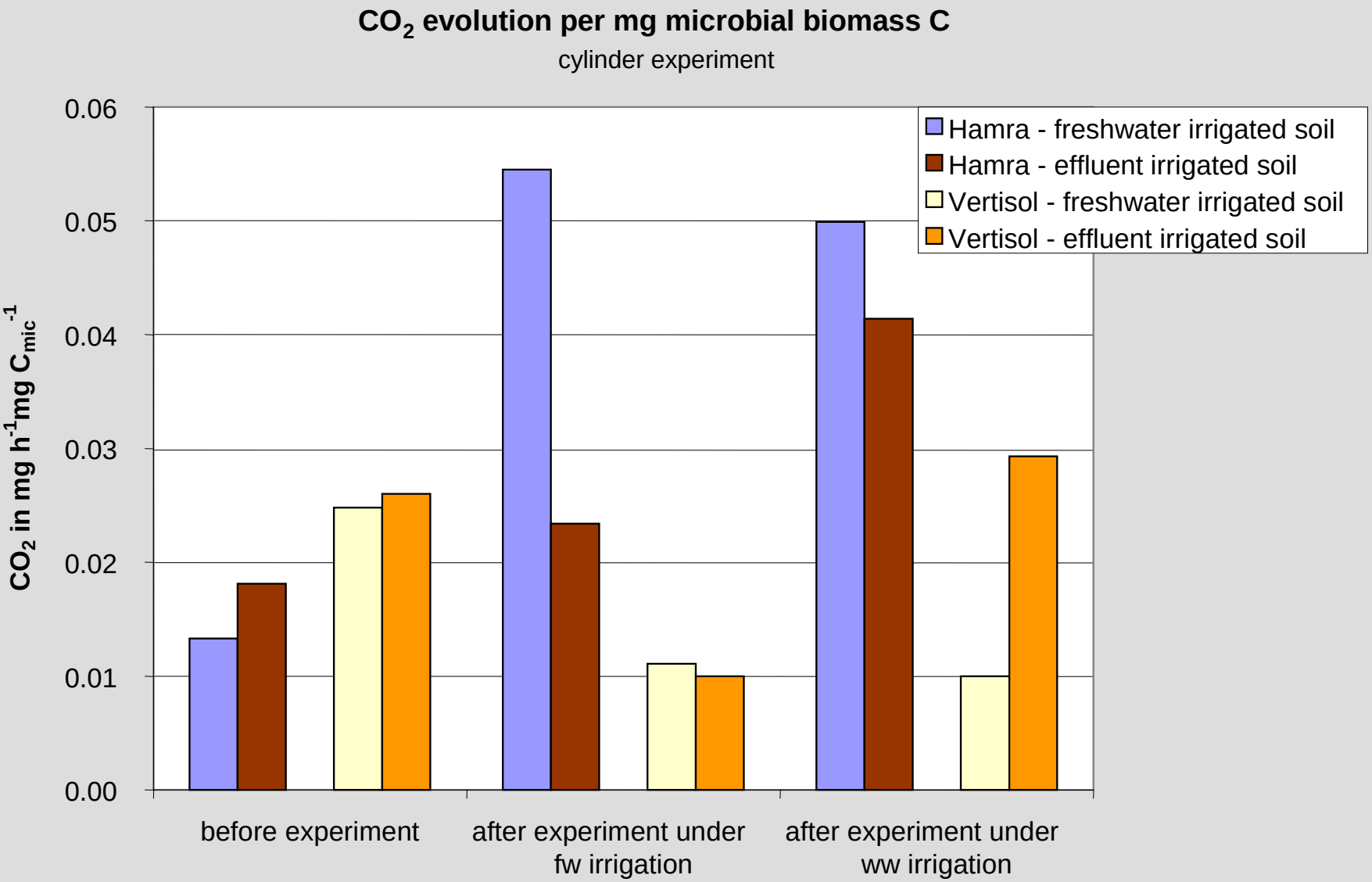
Effects of substrate additions on the mineralization of SOM

(Ramat Hakovesh orchard, 10-20 cm)

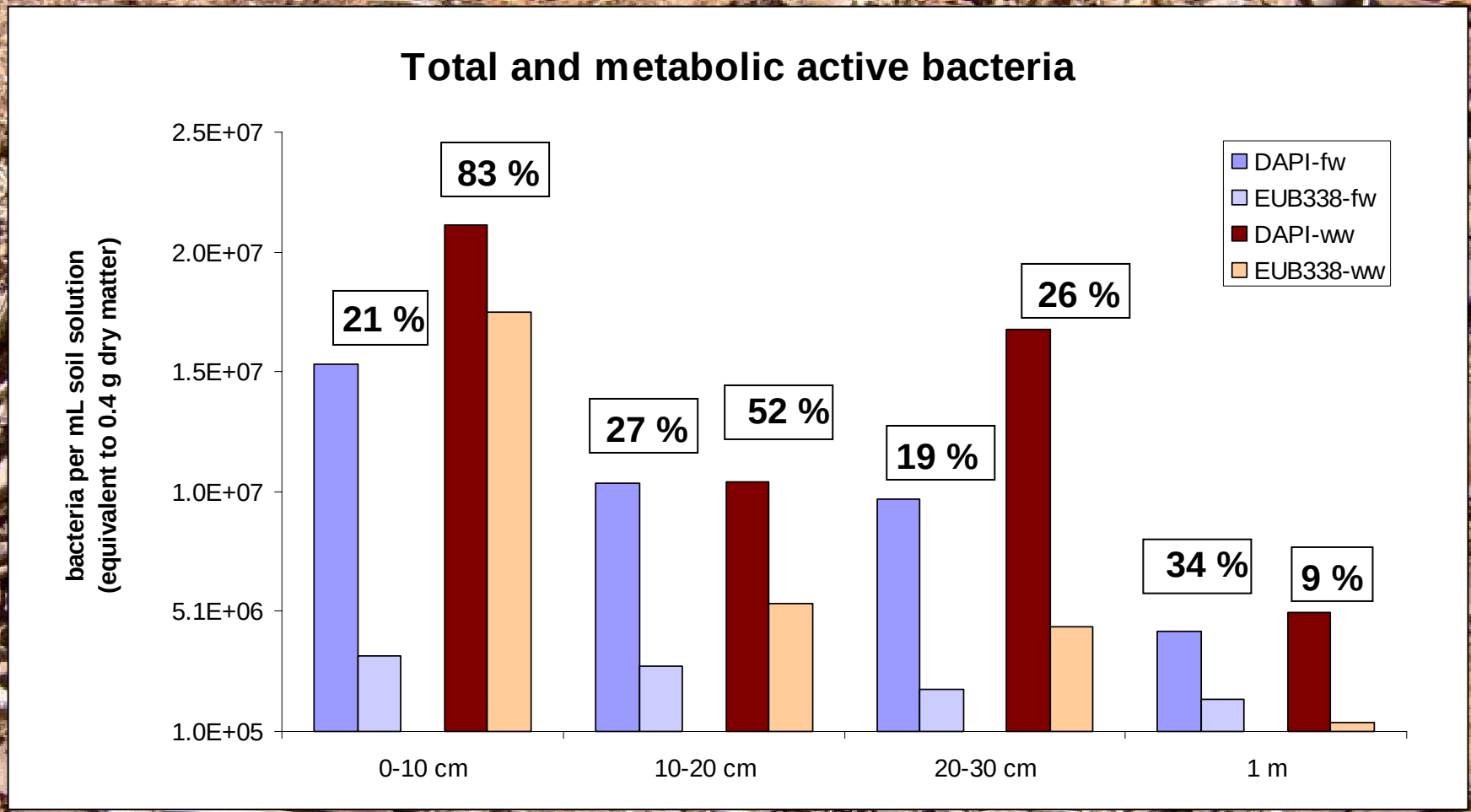


- ➔ Priming effects in freshwater irrigated soil correlate with increased C_{mic}
- ➔ Lack of priming effects in ww soil despite similar substrate utilization indicates that substrates are not limiting microbial activity

Results


CO_2 evolution per mg microbial biomass C
cylinder experiment
CO_2 in mg h^{-1}mg C_{mic}^{-1}
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Hamra - freshwater irrigated soil
Hamra - effluent irrigated soil
Vertisol - freshwater irrigated soil
Vertisol - effluent irrigated soil
before experiment
after experiment under fw irrigation
after experiment under ww irrigation

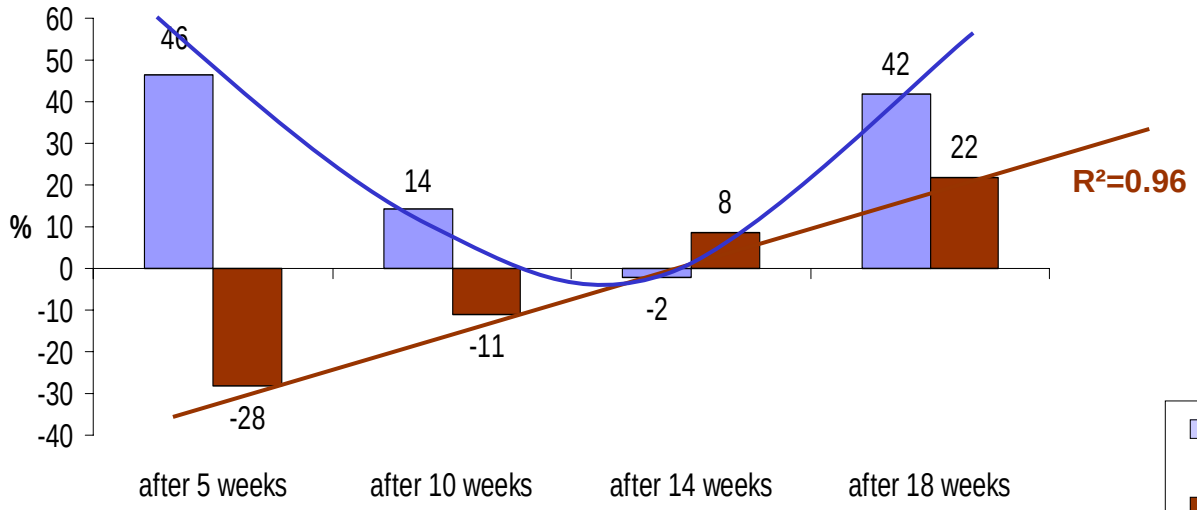
Field experiment HaMa´pil



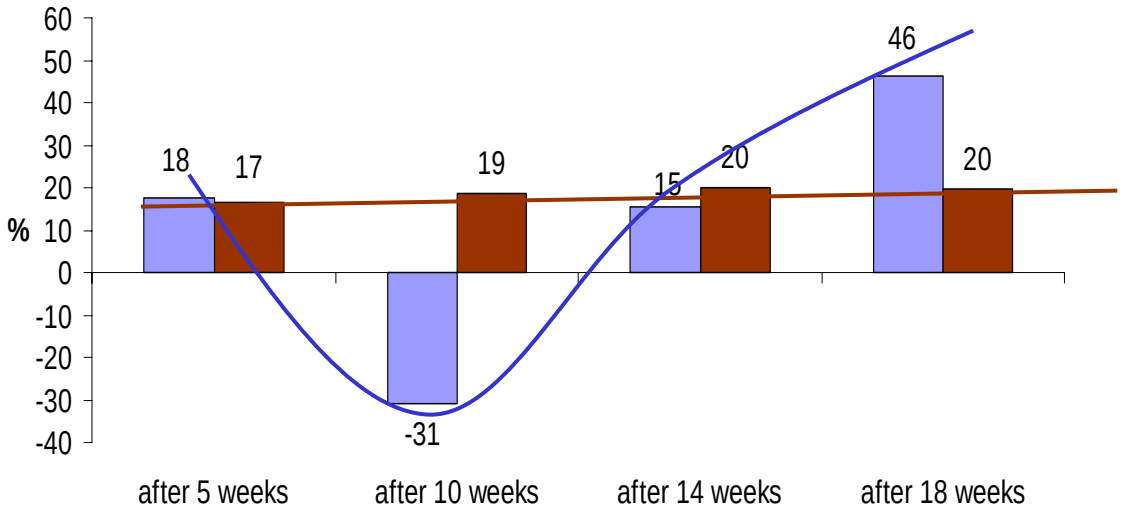
Tab.: C_{org} in %

	0-10 cm	10-20 cm	20-30 cm	1 m
freshwater irrigated soil	2.23	0.49	0.30	0.15
effluent irrigated soil	2.03	1.17	0.92	0.10

Increase of active bacterial cells in % during 4 months of effluent irrigation



Hamra



Vertisol

freshwater irrigated soil

effluent irrigated soil

Land use: Effects of effluent irrigation

Summary

- Irrigation with treated wastewater influences the amount and properties of organic soil components
- Shifts in DOC quality during seasons were observed
- OM level increases in the topsoil of effluent irrigated soils, yet it is depleted from deeper horizons

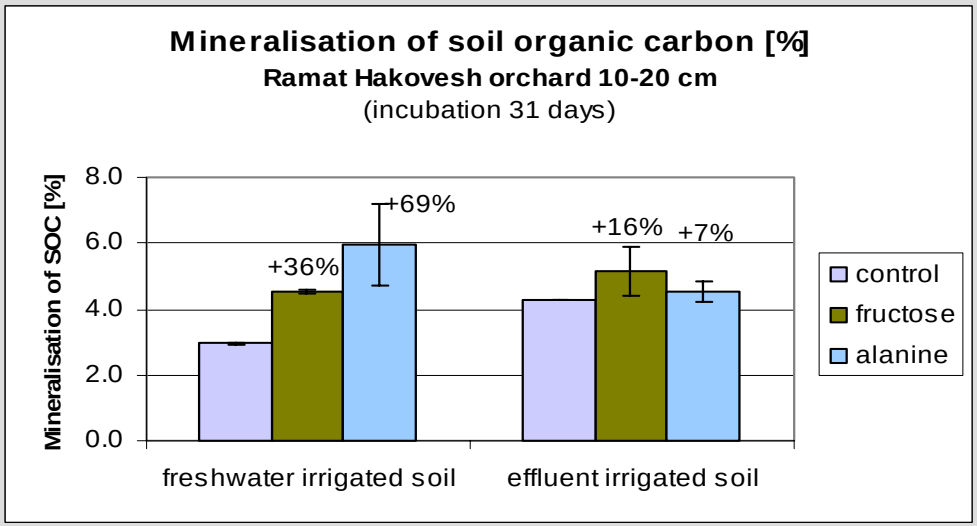
additional DOC as nutrient source in the effluent irrigated soil

⇑

leads to higher mineralisation of SOM, also in deeper horizons

Increased indication of priming effects

Priming Effects



- in effluent irrigated soil higher mineralisation in the control
- addition of substrates results in positive priming effects
- stronger effects in freshwater irrigated soils

effluent water contains fresh organic substrates, which enhance the mineralisation of SOM already in the field

in these soils **priming** may occur directly after addition of effluent water, easy available pool in the soil is used all the time