Effect of irrigation with reclaimed wastewater on soil hydrophobicity and hydraulic conductivity

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Background

1. Fresh water shortage in Israel forces farmers to irrigate with effluents.

2. Effluents comprise about 30% of the agricultural water consumption.

3. Farmers using water with TOC levels of 40-70 mg L^{-1} reported a unique water distribution regime.

4. These farmers were forced to place the drippers more densely aiming to ensure overlapping between wetted areas.

Hypothesis

Organic component exhibiting hydrophobic properties which reach the soil with the effluents, influence the degree of water/soil repellency and thus affect the water distribution in the soil.

General objective

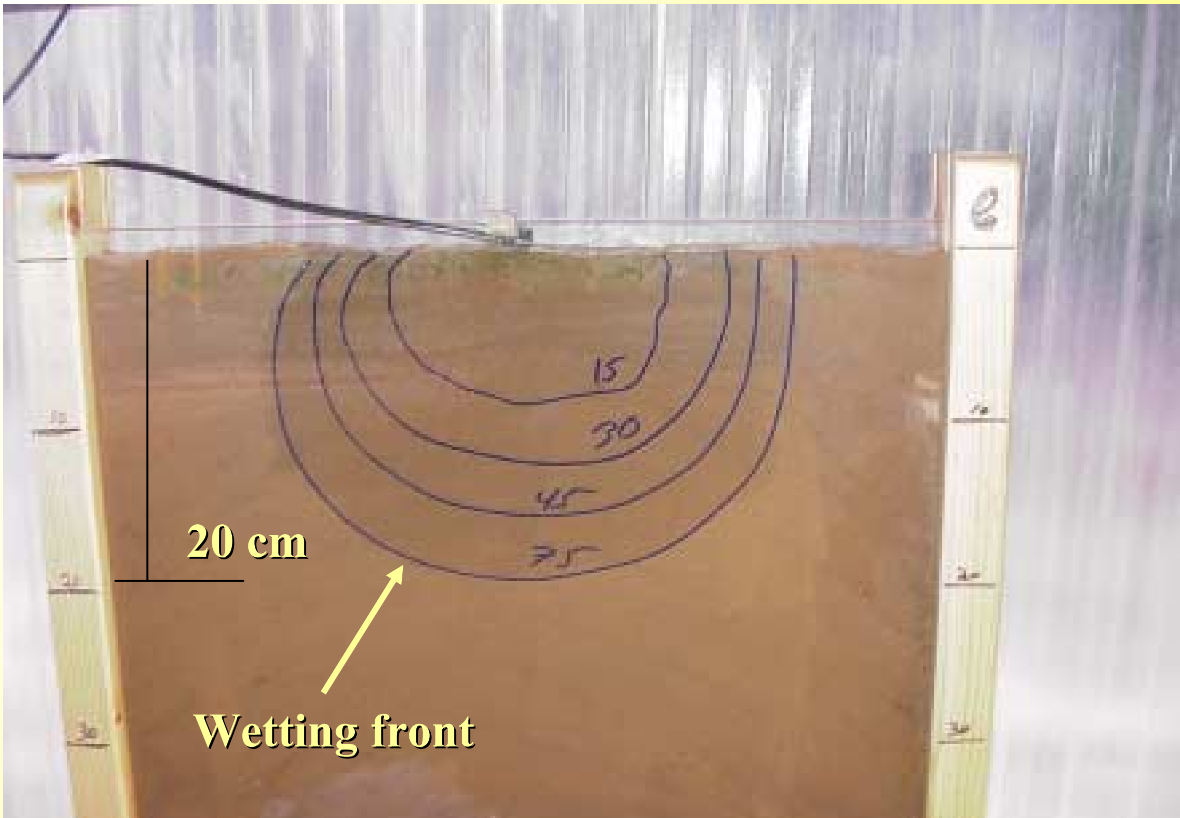
To verify the hypothesis and provide explanation to the mechanisms involved.

Hydrophobicity in sand irrigated with effluents

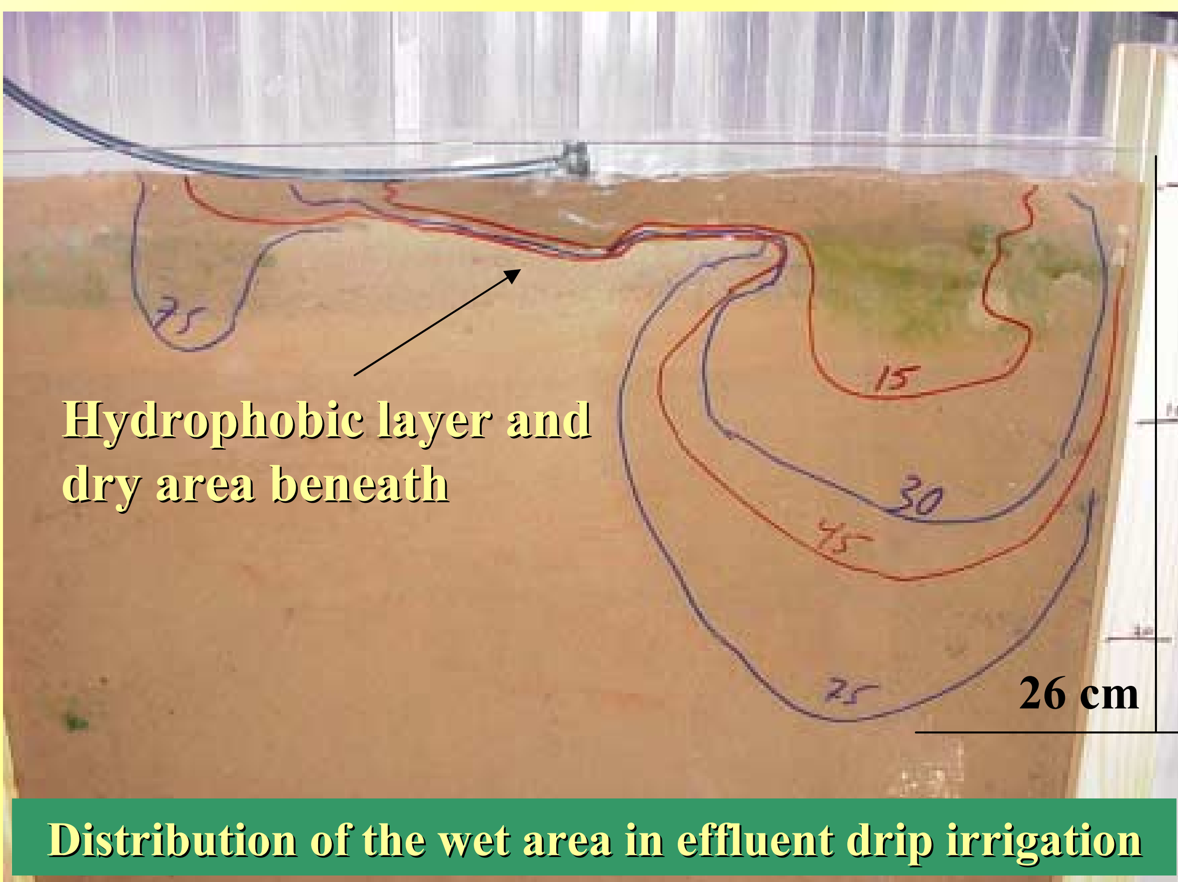
Disappearance of the ponded area in sand irrigated with effluents (after 30 seconds)

Normal ponded area in sand irrigated with fresh water

Hydrophobic flow in sand irrigated with effluents



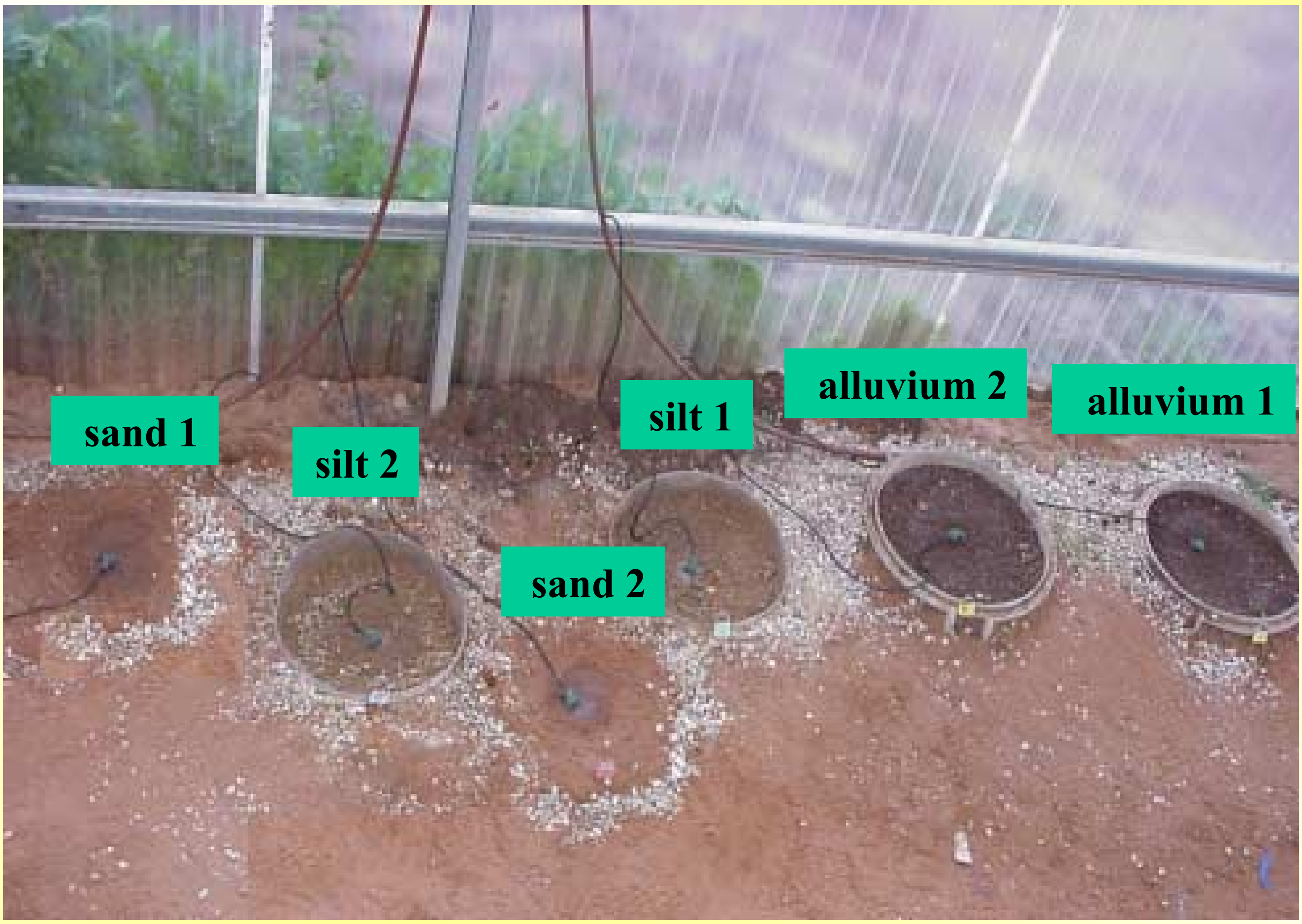
Distribution of the wet area in fresh water drip irrigation



Distribution of the wet area in effluent drip irrigation

Experimental details

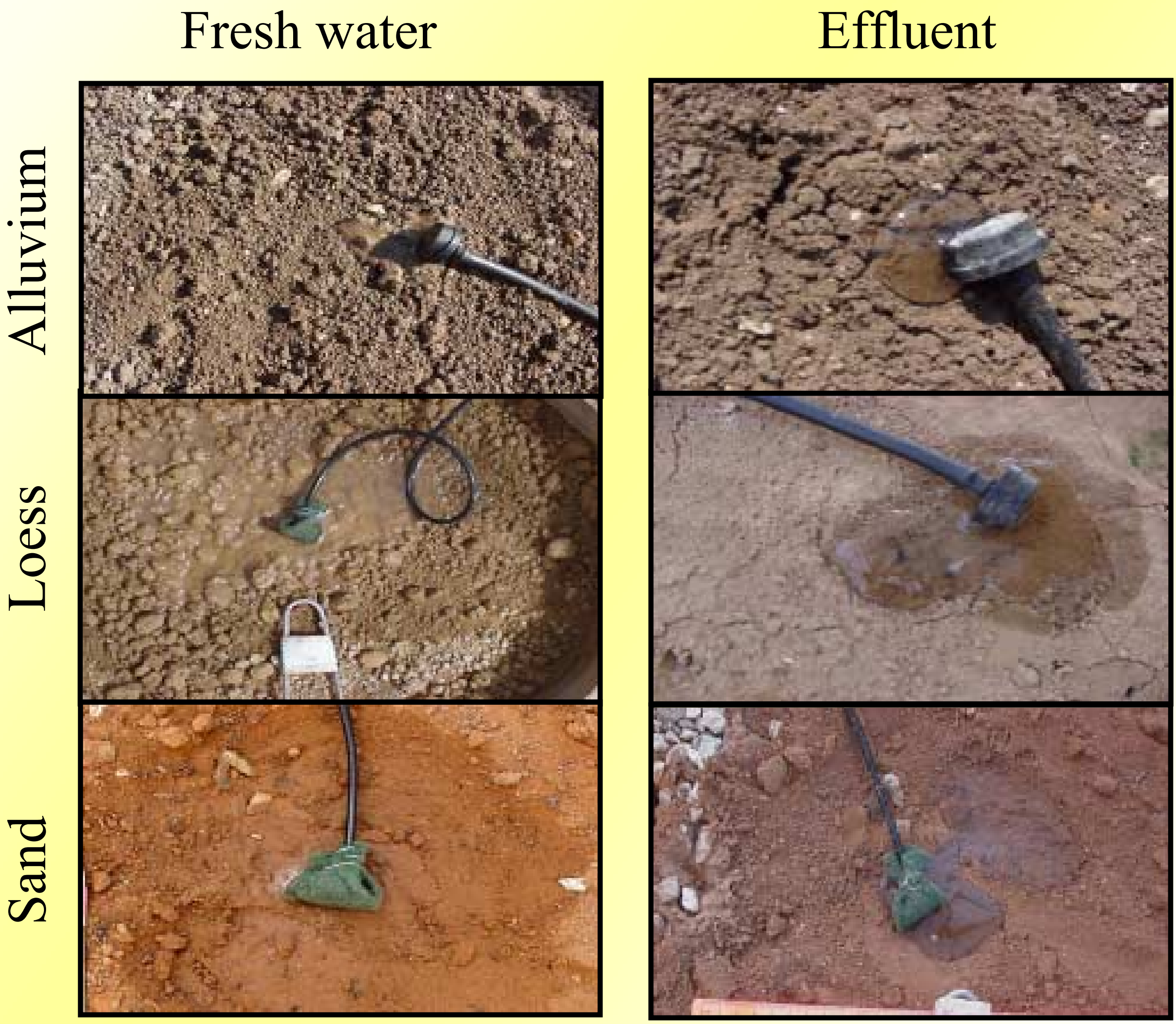
Changes in water distribution in soils irrigated with fresh and effluent water



Soils examined (A- Laboratory ; B- Field)

A. - Sand, silt and alluvium (soils that were not previously irrigated with effluents).
- 1,2 : replicates

B. Alluvial soils from Gaaton and Gvat that were irrigated with effluents during the last few years.


Fresh water
Effluent
Alluvium
Loess
Sand

Saturated area diameter (cm) in sand, silt and alluvium soils irrigated with fresh and effluent water

	alluvium		silt		sand	
	alluv 1	alluv 2	silt 1	silt 2	sand 1	sand 2
fresh water*	7	5	14	12	6.5	8
	* Based on the result from the former test					
effluent	3	3.5	8	5	6	6
standard deviation	0	0.5	0.6	0.3	0.8	0.5

•Measurements were conducted at a discharge of 3.6 l/h for sand and alluvium and 1 l/h for silt (fresh and effluent).

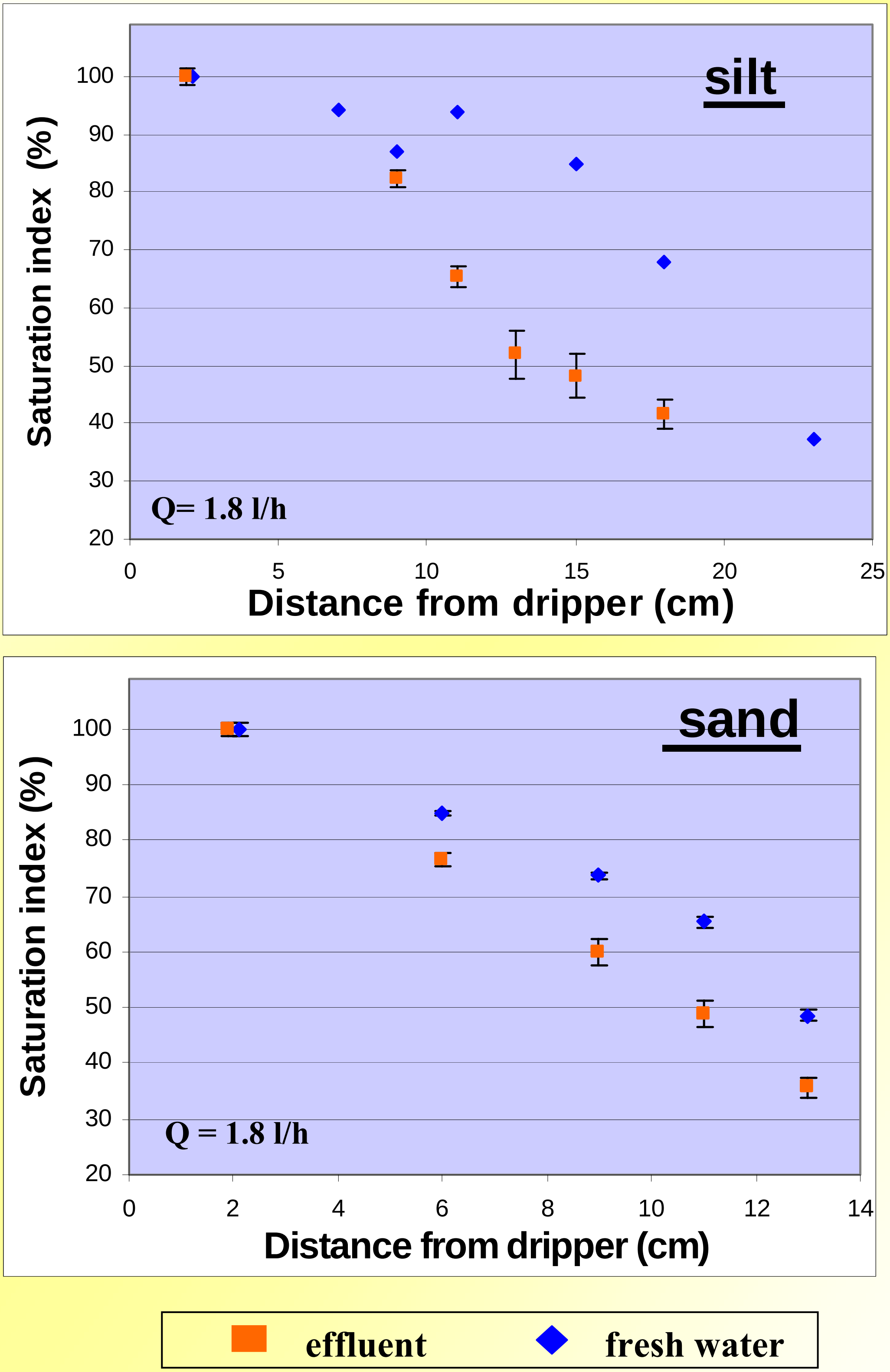
•Measurements on effluents were conducted after 10 drip irrigation cycles with a volume of 1 l per irrigation.

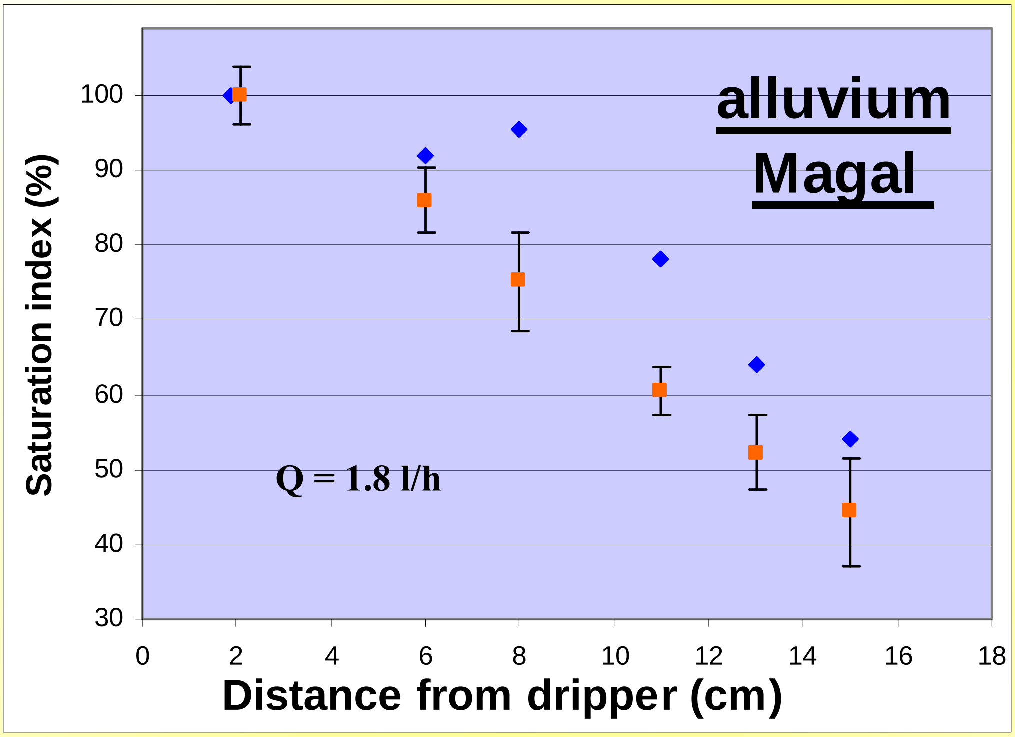
Soil water content - represented as saturation index, vs. the distance from the dripper in sand, silt, alluvium (Magal and Gaaton) soils

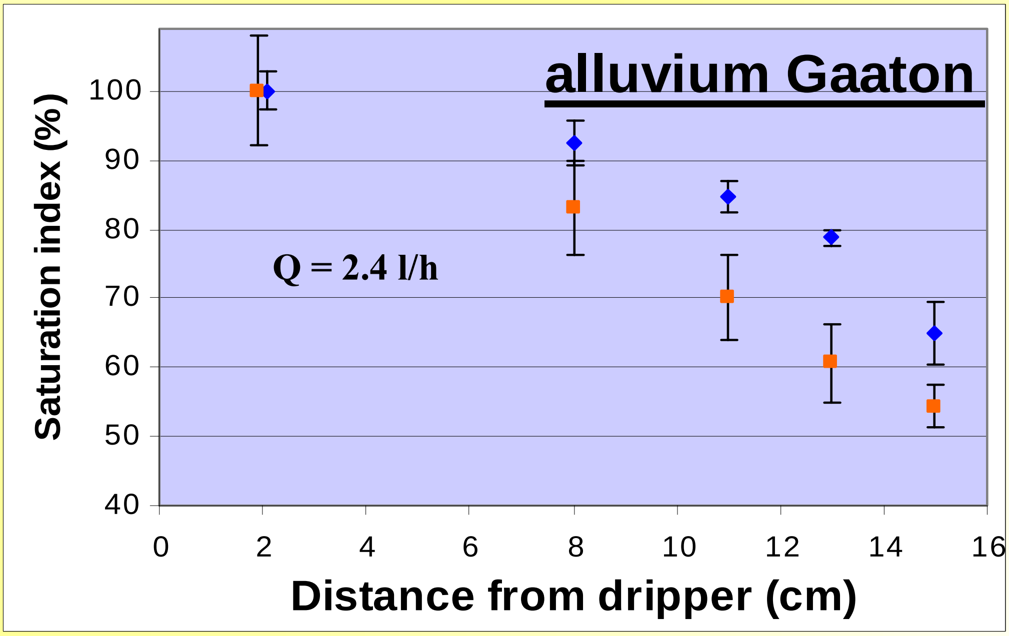
The average water content was measured at a depth of 0-10 cm after 30 minute of drip irrigation, using TDR.

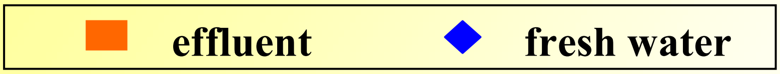
The measurements were conducted after the soils (sand, silt and alluvium (Magal)) were irrigated 10 times with a volume of 1 liter per irrigation.

The alluvium (Gaaton) soil was irrigated with effluents during the last few years.


silt
Saturation index (%)
100
90
80
70
60
50
40
30
20
Q= 1.8 l/h
0
5
10
15
20
25
Distance from dripper (cm)
sand
Saturation index (%)
100
90
80
70
60
50
40
30
20
Q = 1.8 l/h
0
2
4
6
8
10
12
14
Distance from dripper (cm)
effluent
fresh water


alluvium
Magal
Q = 1.8 l/h
Saturation index (%)
Distance from dripper (cm)
100
90
80
70
60
50
40
30
0
2
4
6
8
10
12
14
16
18


alluvium Gaaton
Q = 2.4 l/h
Saturation index (%)
Distance from dripper (cm)
100
90
80
70
60
50
40
0
2
4
6
8
10
12
14
16


effluent
fresh water

Summary of observations

Effluent irrigation resulted in:

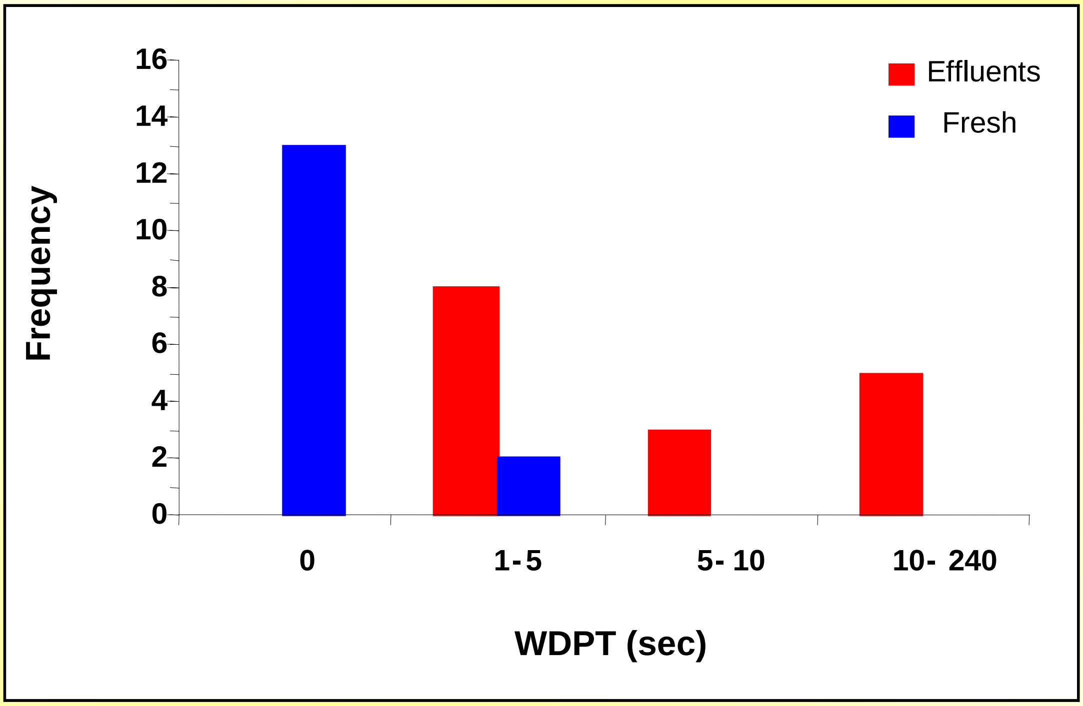
1. Decrease in the diameters of the saturated area.
2. Decrease in the degree of saturation.
3. Shifts in the water distribution regime.

Water drop penetration time* and estimation of the degree of hydrophobicity in the alluvium soil (Gaaton) irrigated with effluents and fresh water

soil irrigated with effluents			soil irrigated with fresh water	
Degree of hydrophobicity (estimation)	WDPT (sec)	sample No.	WDPT (sec)	sample No.
no hydro	2	1	0	1
weak hydro	6	2	0	2
no hydro	2	3	0	3
weak hydro	4	4	0	4
weak hydro	10	5	0	5
no hydro	3	6	0	6
medium hydro	60	7	0	7
no hydro	2	8	0	8
medium hydro	40	9	0	9
no hydro	3	10	2	10
no hydro	2	11	0	11
weak hydro	15	12	0	12
weak hydro	5	13	0	13
no hydro	3	14	2	14
severe hydro	240	15	0	15

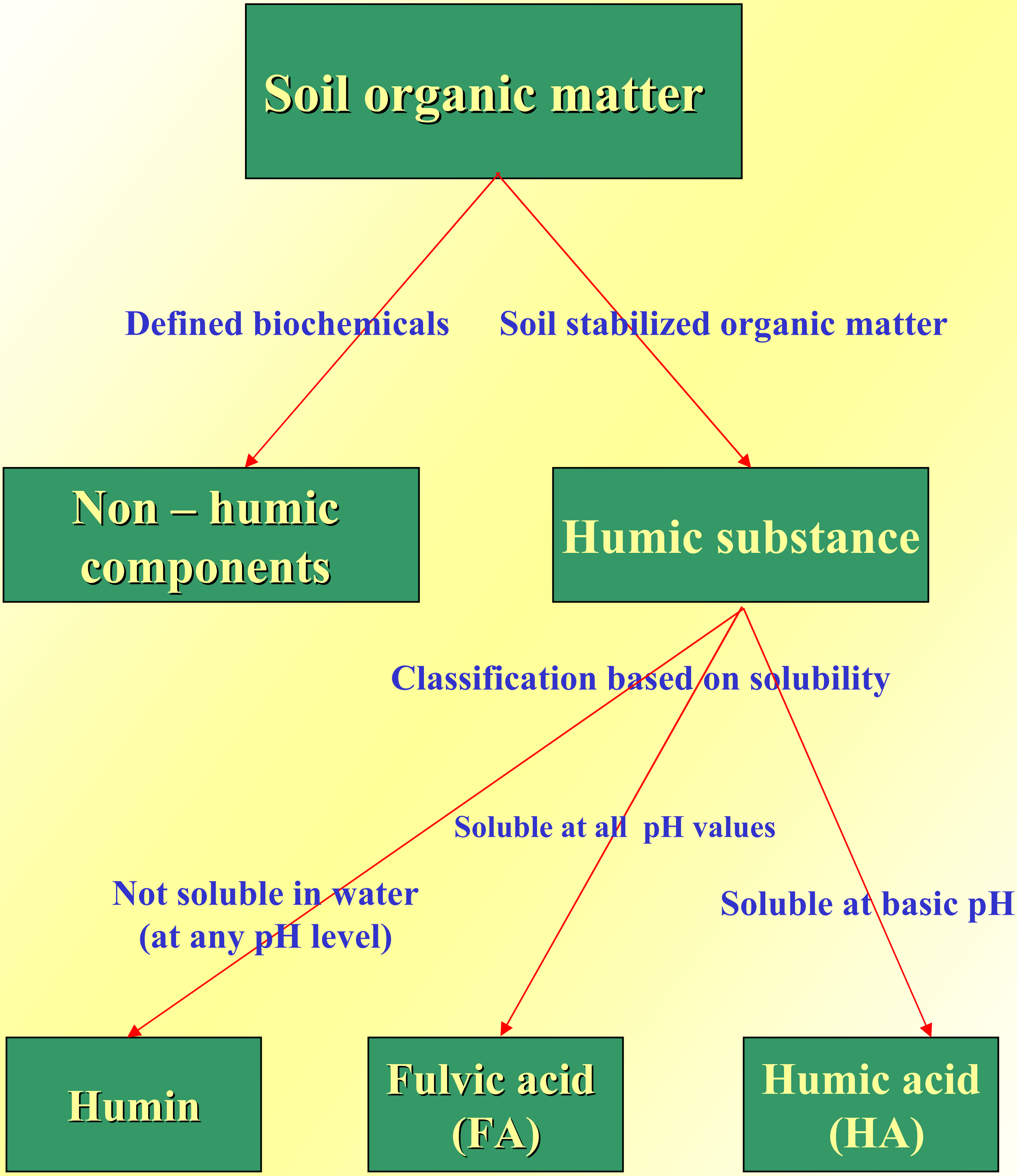
*WDPT- a known index for the evaluation of the Degree of soil hydrophobicity (time required for penetration of a water drop into the soil).

Frequencies of hydrophobic/non-hydrophobic soil samples

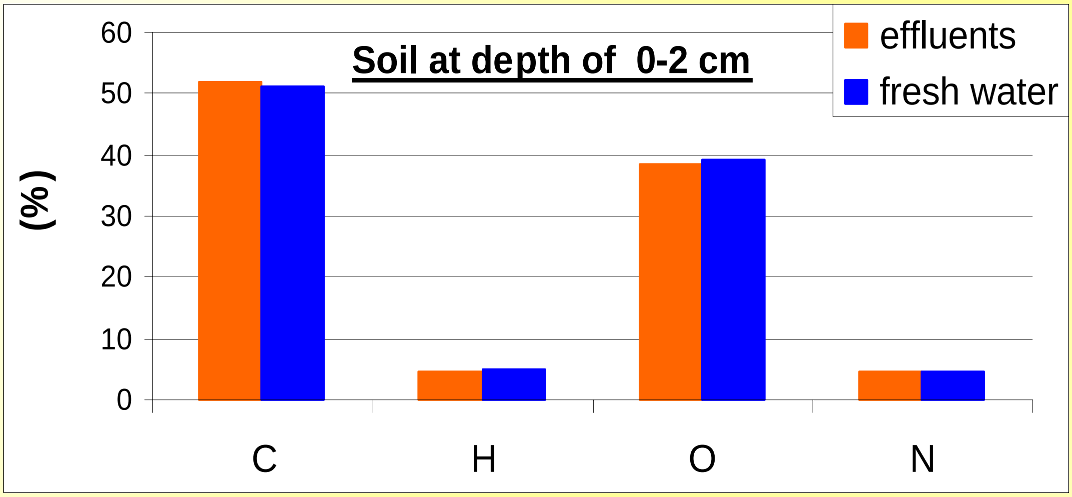


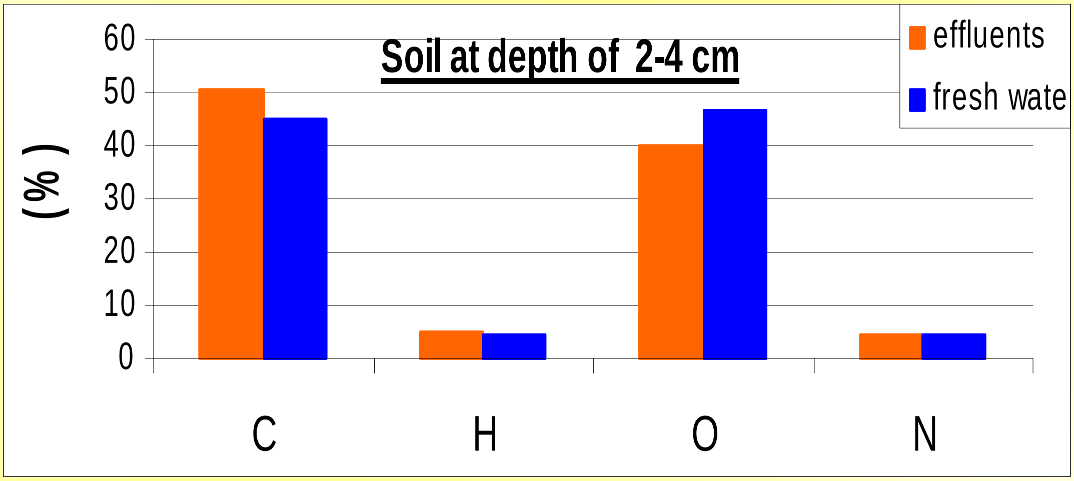
Extraction methods used to characterize soil organic matter

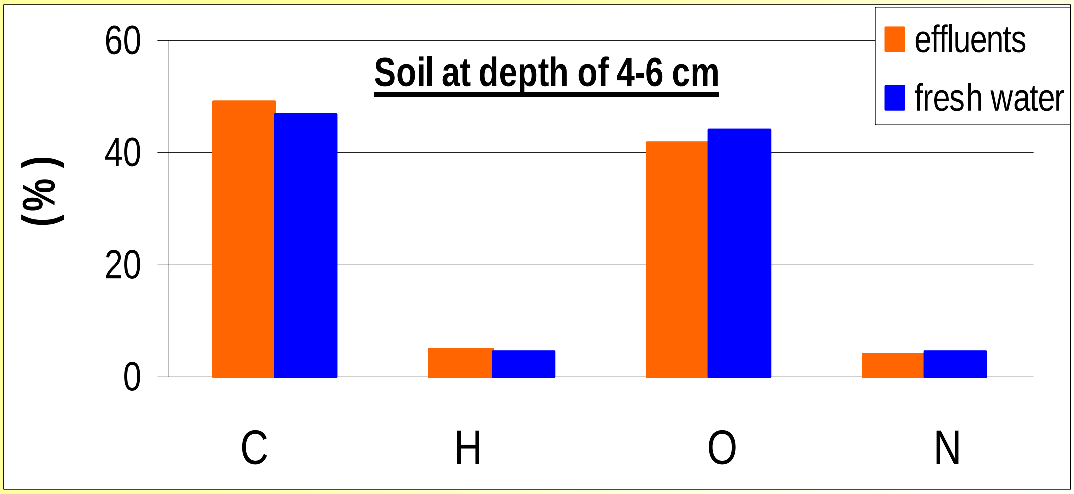
- Soil organic matter
  - Extraction with organic Solvents (methanol + chloroform)
    - Hydrophobic materials (waxes, resins, fats)
  - Extraction of HS with Base (separation to FA and HA with acid)
    - HA, FA, humin


Soil organic matter
Defined biochemicals
Soil stabilized organic matter
Non – humic components
Humic substance
Classification based on solubility
Soluble at all pH values
Not soluble in water (at any pH level)
Soluble at basic pH
Humin
Fulvic acid (FA)
Humic acid (HA)

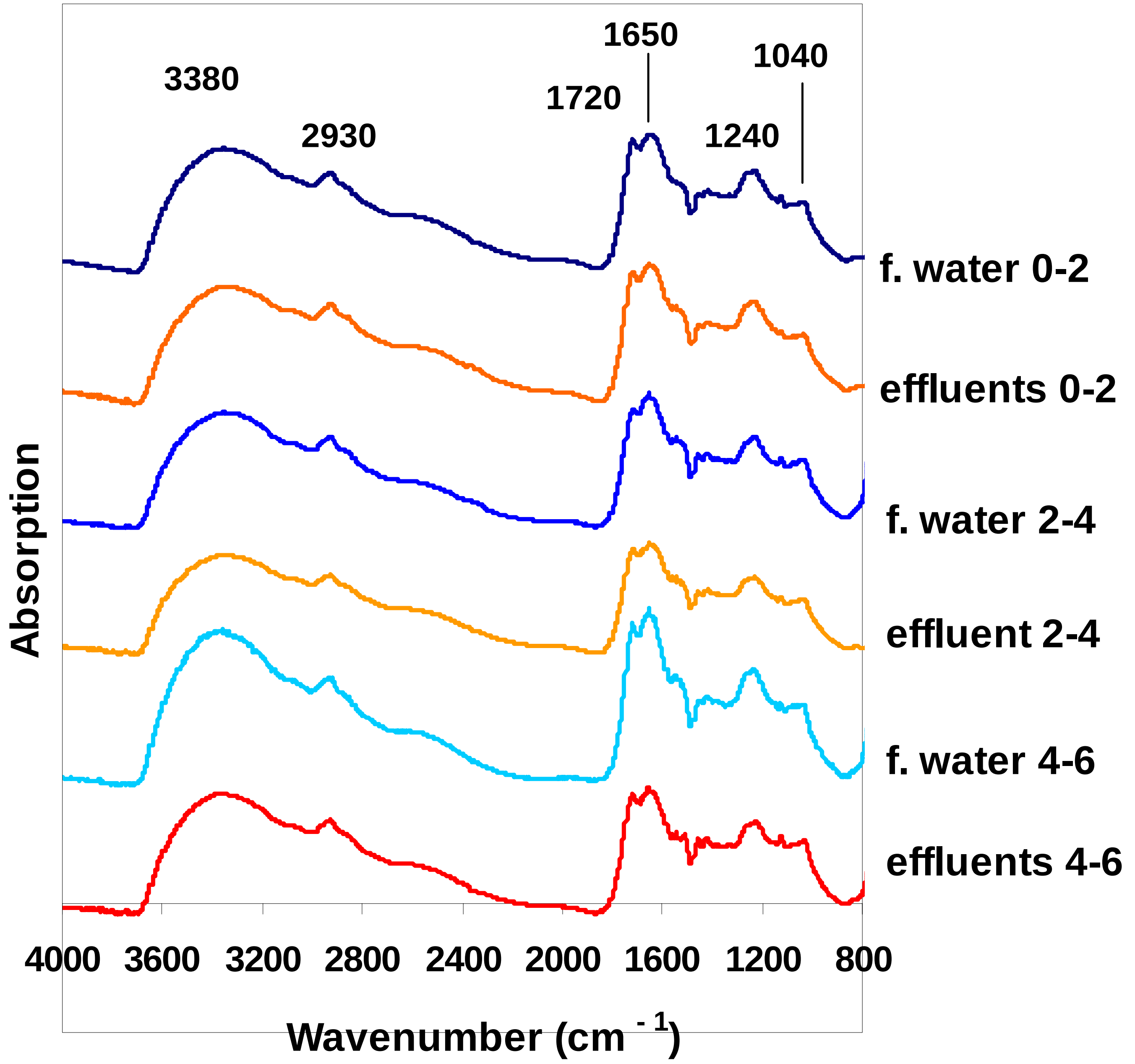
Elemental analysis of HAs extracted from soils irrigated with fresh water or effluents (alluvium; Gaaton)







Infra-red spectra (FTIR*) of HAs extracted from the alluvium soil (Gaaton) at various depth. Soil was irrigated with fresh or effluent water.



*Infra-red absorption spectra of intra-molecular asymmetric bonds

bond	absorption range
C-H aliphatic	2,930
COOH	1,720
C-C aromatic	1650
C-O aromatic	1240
C-O polysaccharides	1040

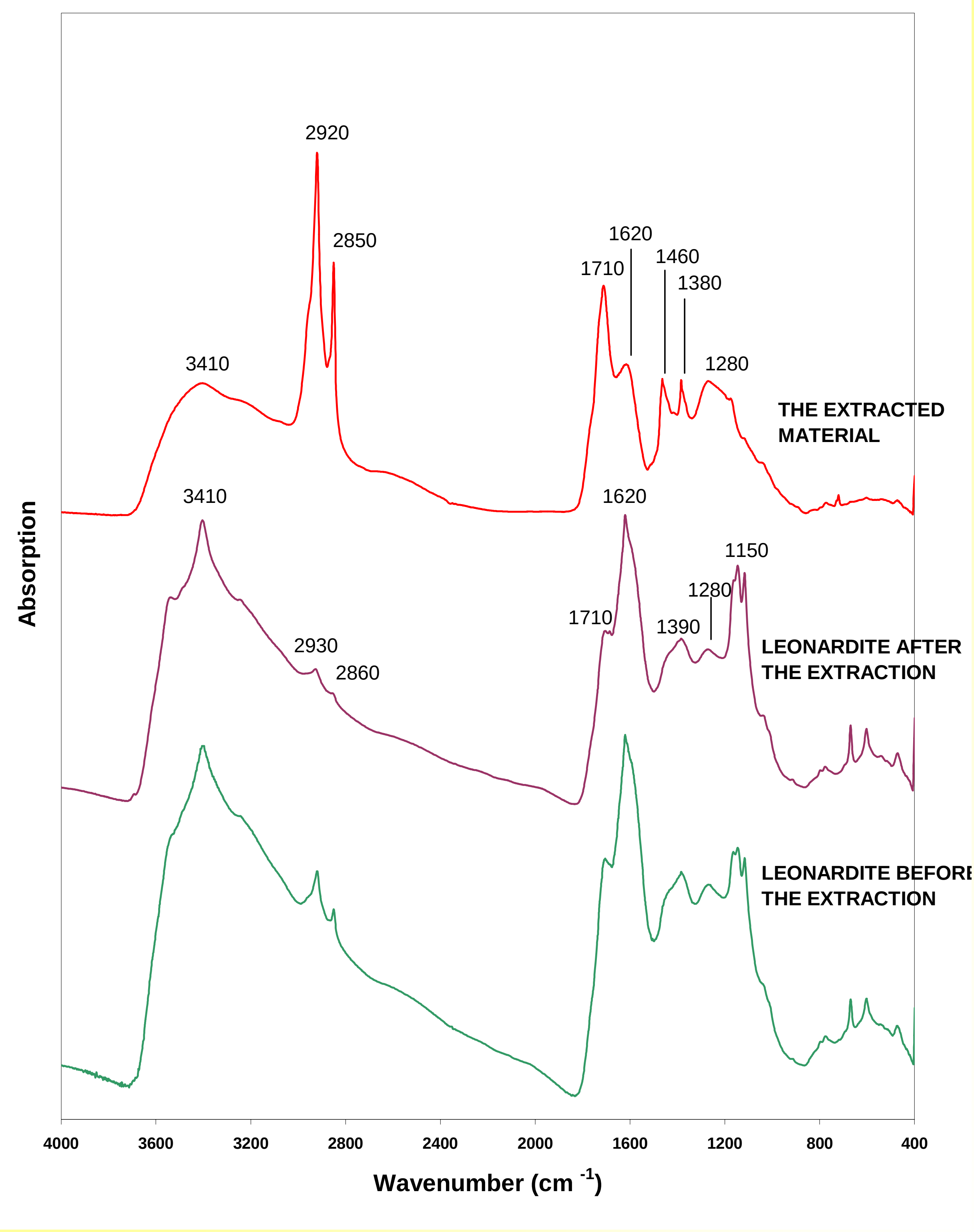
Effects of a chloroform + methanol extraction (1:1) on the hydrophobicity of leonardite

WDPT	MED**	
60 min	3.1 M	leonardite* before solvent extraction
5 sec	0.2 M	leonardite after solvent extraction

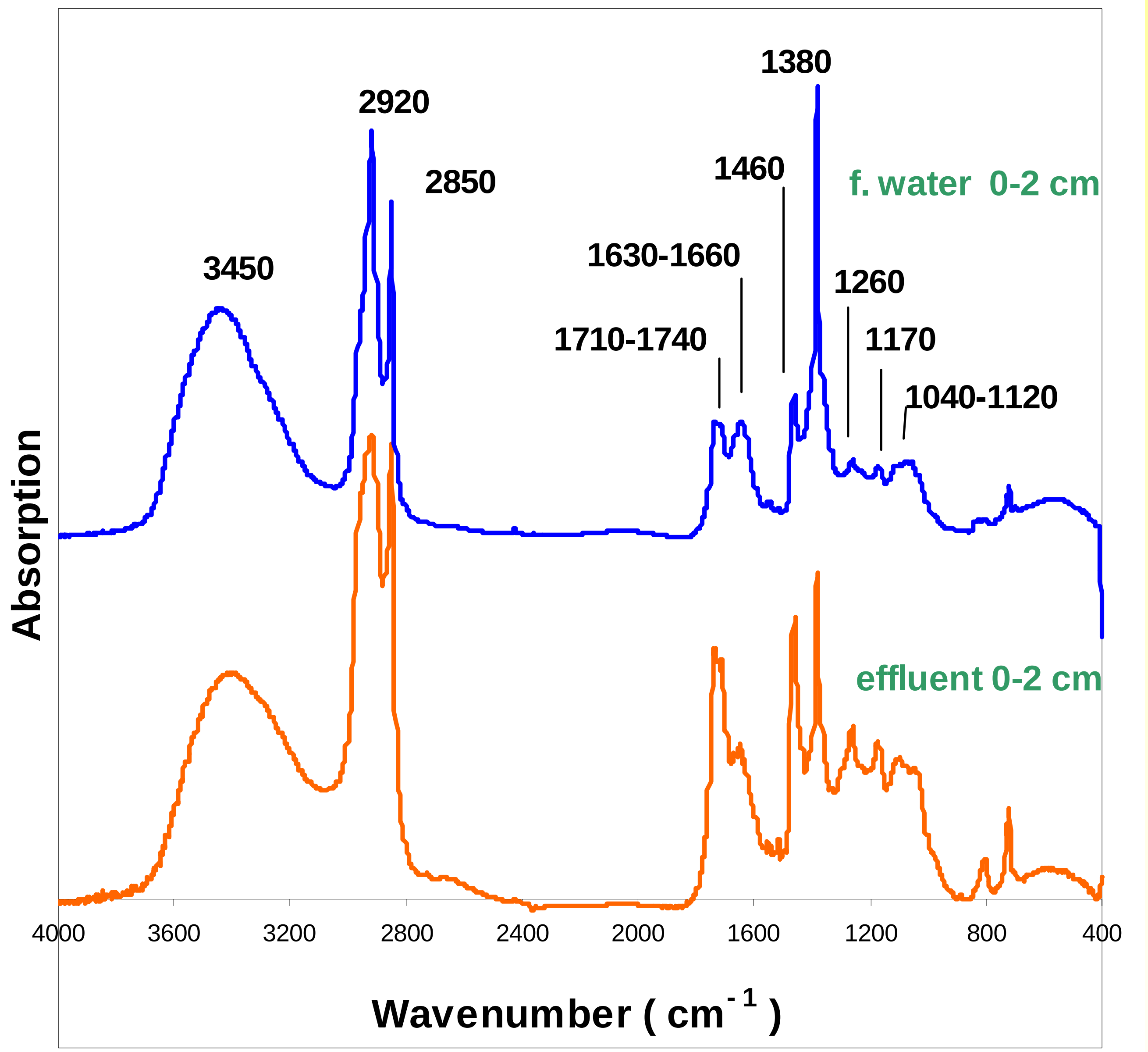
*leonardite is a highly humified OM rich in HA and was found to be highly hydrophobic.

**MED: The molarity of ethanol in the drop of water which does not penetrate to the soil within at least 5 sec.

Infra-red spectra (FTIR) of Leonardite

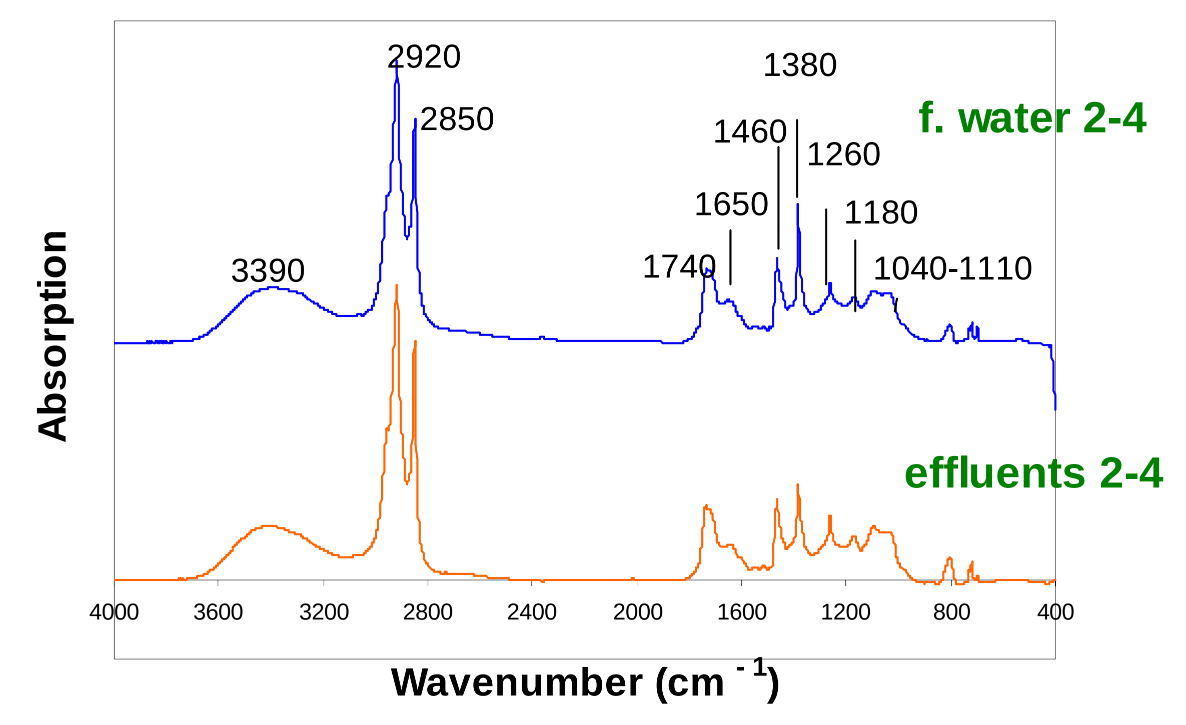


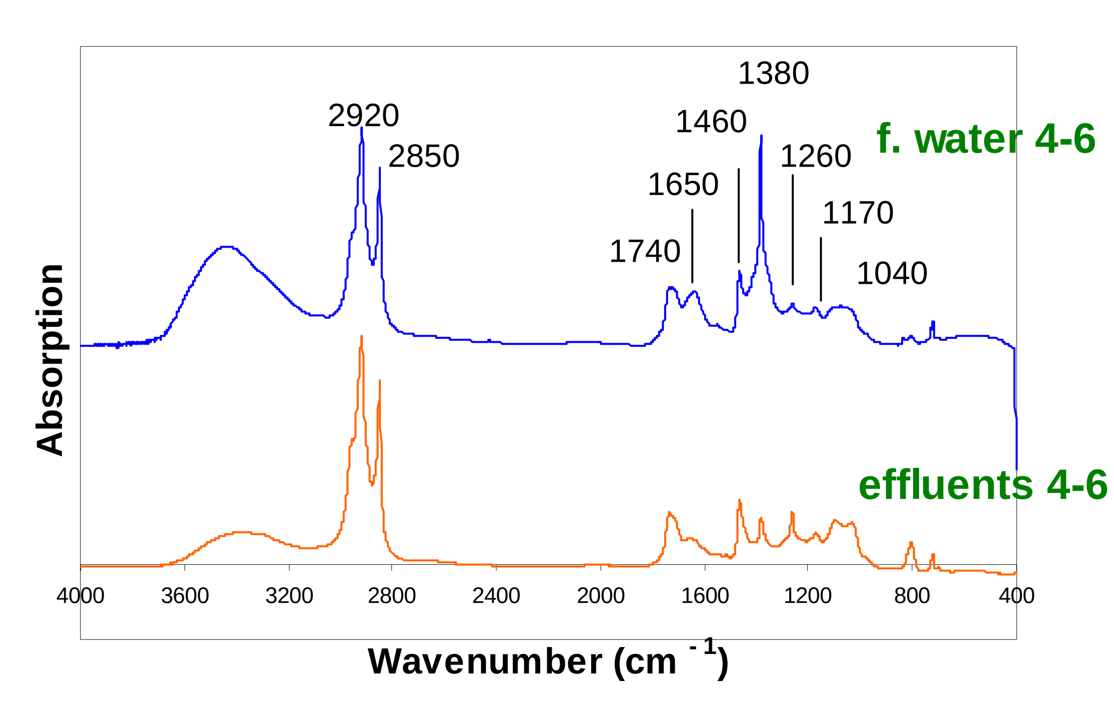
Infra-red spectra (FTIR) of solvent extracted (chloroform + methanol) components obtained from the alluvium (Gaaton) irrigated with fresh or effluent water (0-2 cm).



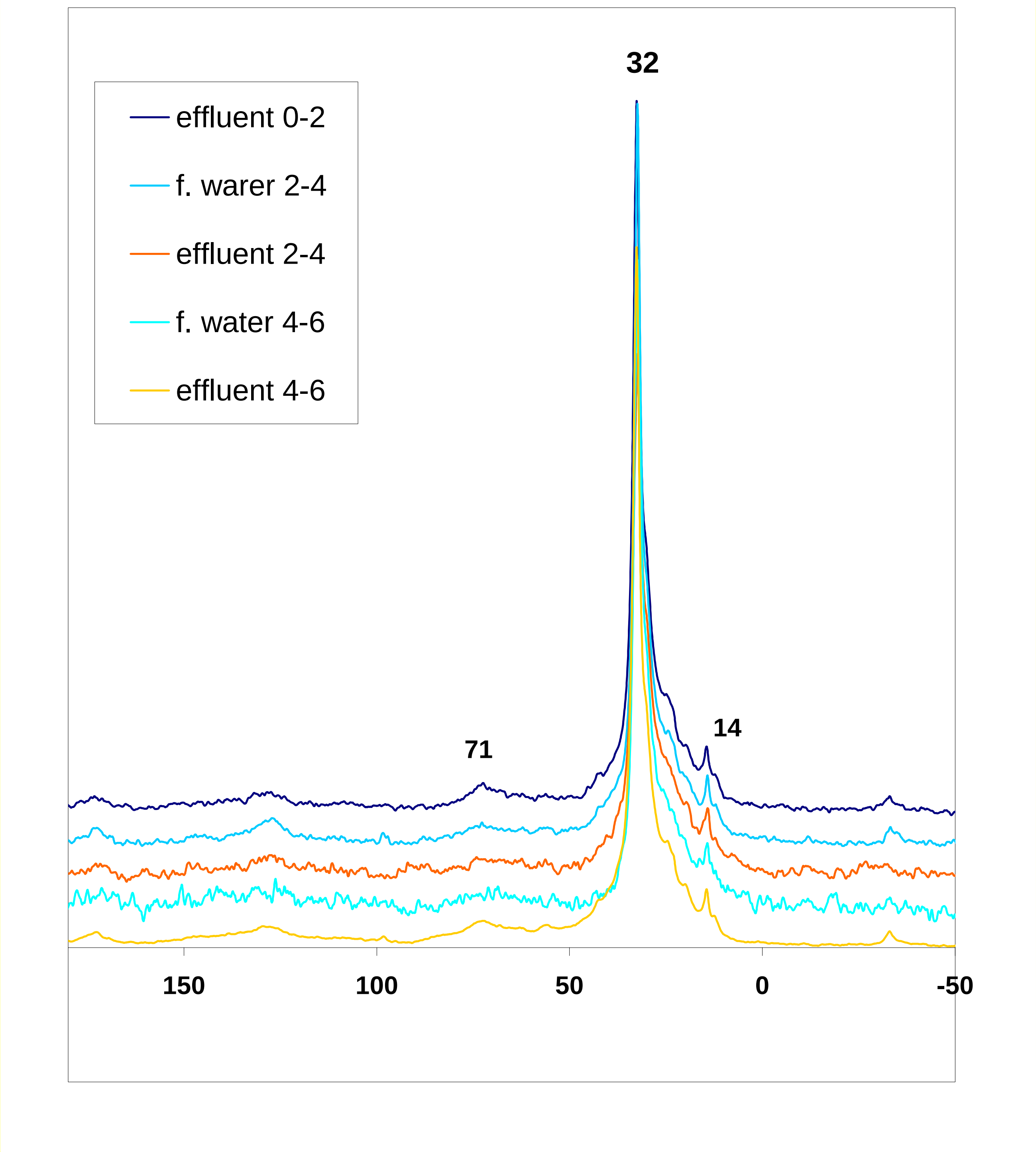
bond	absorption range
C-H aliphatic	2920 ,2850, 1460
C-C aromatic	1650
N-O	1380
C-O aromatic	1260
C-O polysaccharides	1170 ,1110, 1040

Infra-red spectra (FTIR) of solvent extracted (chloroform + methanol) components obtained from the alluvium (Gaaton) irrigated with fresh or effluent water (2-4 & 4-6 cm).





13C-NMR spectra of solvent extracted (chloroform + methanol) components obtained from the alluvium (Gaaton) irrigated with fresh or effluent water (0-2; 2-4; 4-6 cm).



Summary of observations

1. Water repellency was induced by irrigation with effluents.

2. HS were identical in fresh water and/or effluent irrigated soils (FTIR, ^{13}C-NMR).

3. Solvent extraction removes hydrophobicity.

4. Highly aliphatic compounds were found in solvent extracts.

5. Structural differences were distinctive in the 0-2 cm layer only.

Conclusions

1. Soils irrigated with effluents exhibited elongated and shifted wet areas as opposed to the “classical” “onion shaped” wet area under the dripper known to form with fresh water irrigation.

2. Hydrophobic organic compounds ccumulating on the top thin layer of the soil (0-2 cm) induce water repellency and distorted water distribution regime.

3. Quantification of the above is the next essential step.

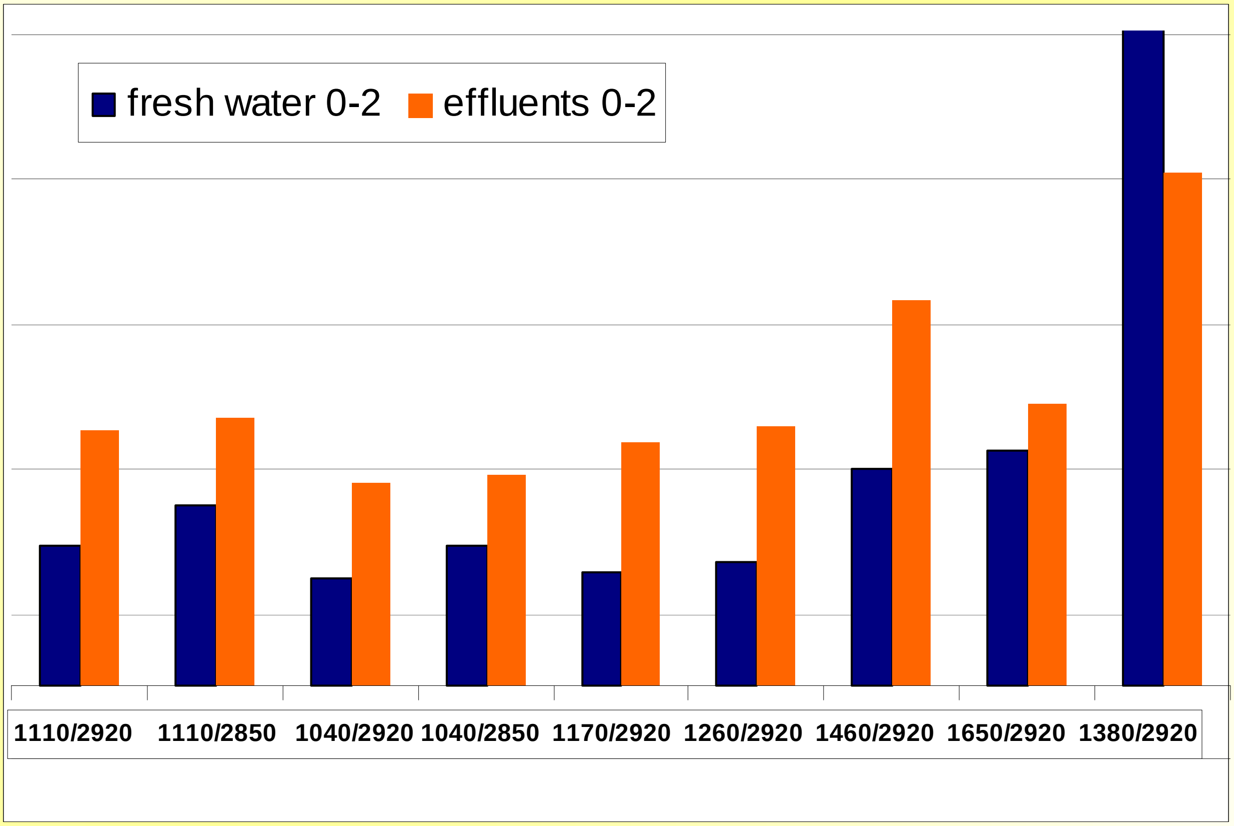
THANK YOU

QUESTIONS?

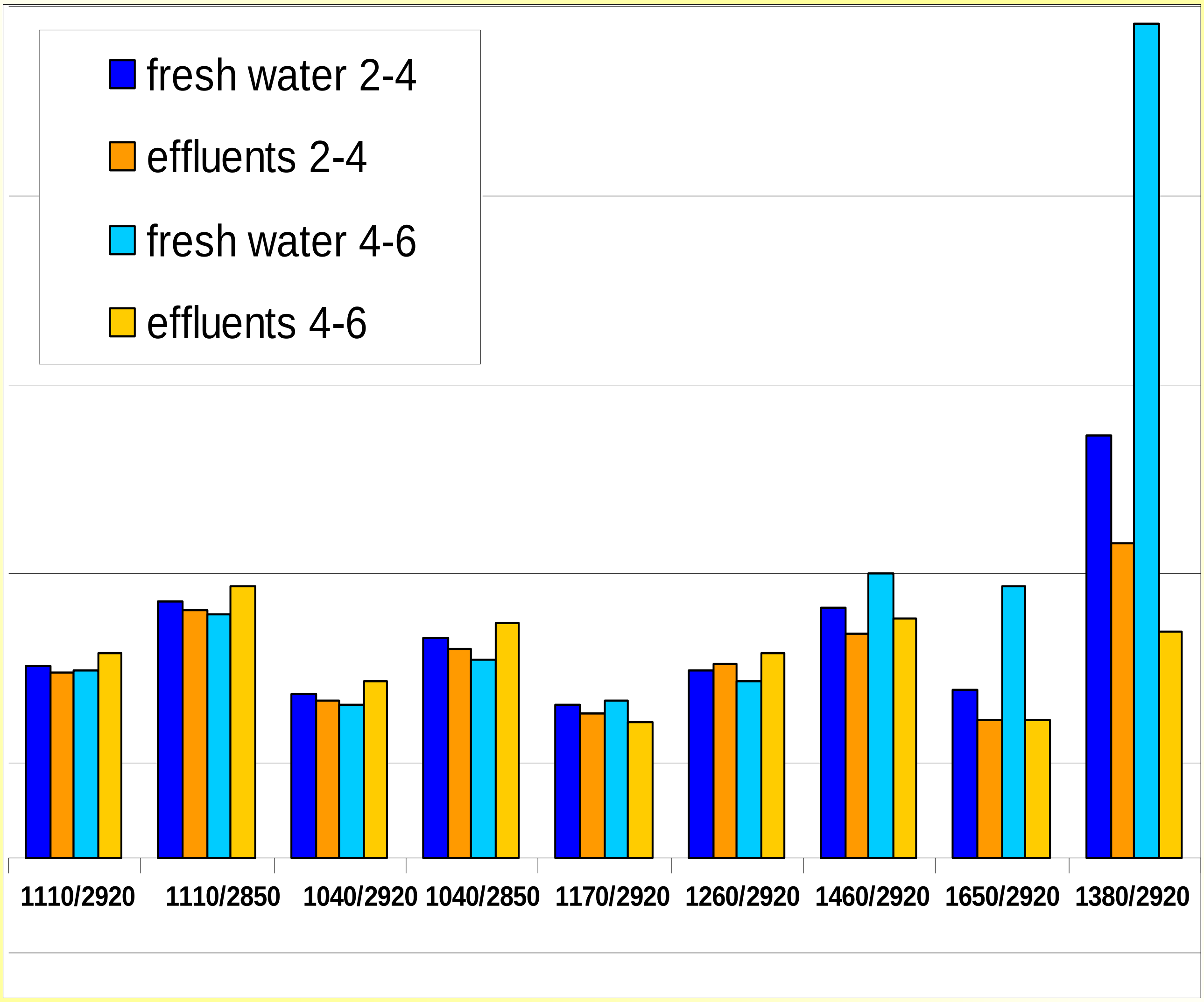
Hydrophobicity in soil irrigated with effluents in Gvat

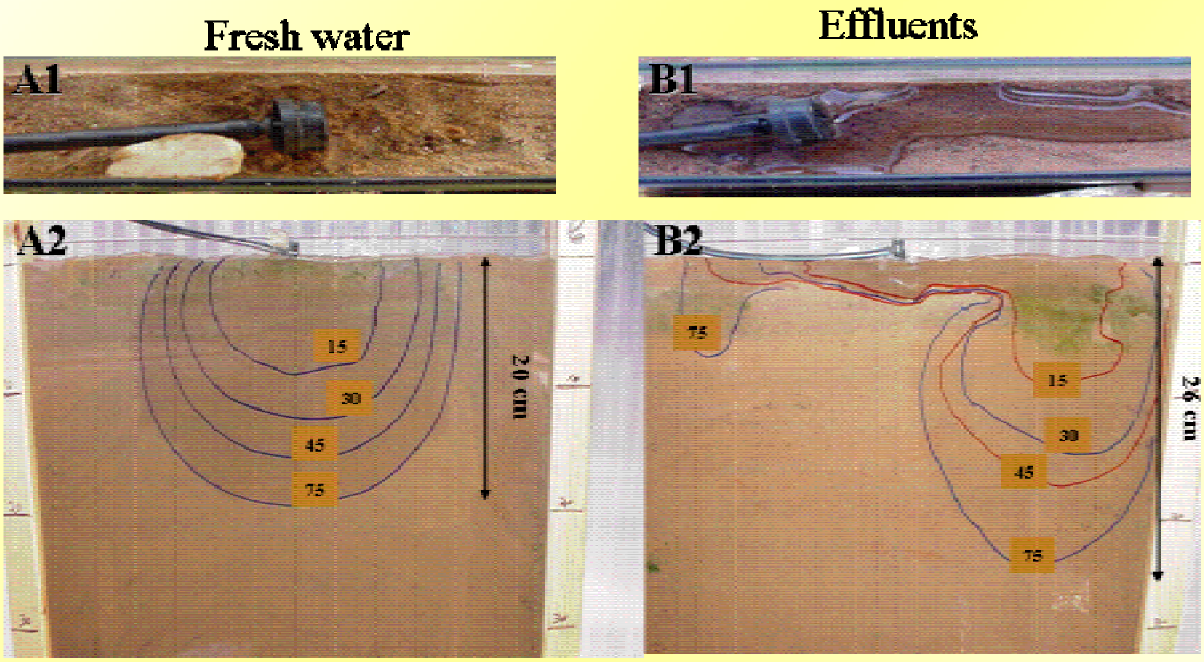
Hydrophobicity in soil irrigated with effluents in Gvat

Peak ratios for infrared spectra (FTIR) of organic components solvent extracted (chloroform + methanol) from the alluvial soil (Gaaton) irrigated with fresh or effluent water (0-2 cm).

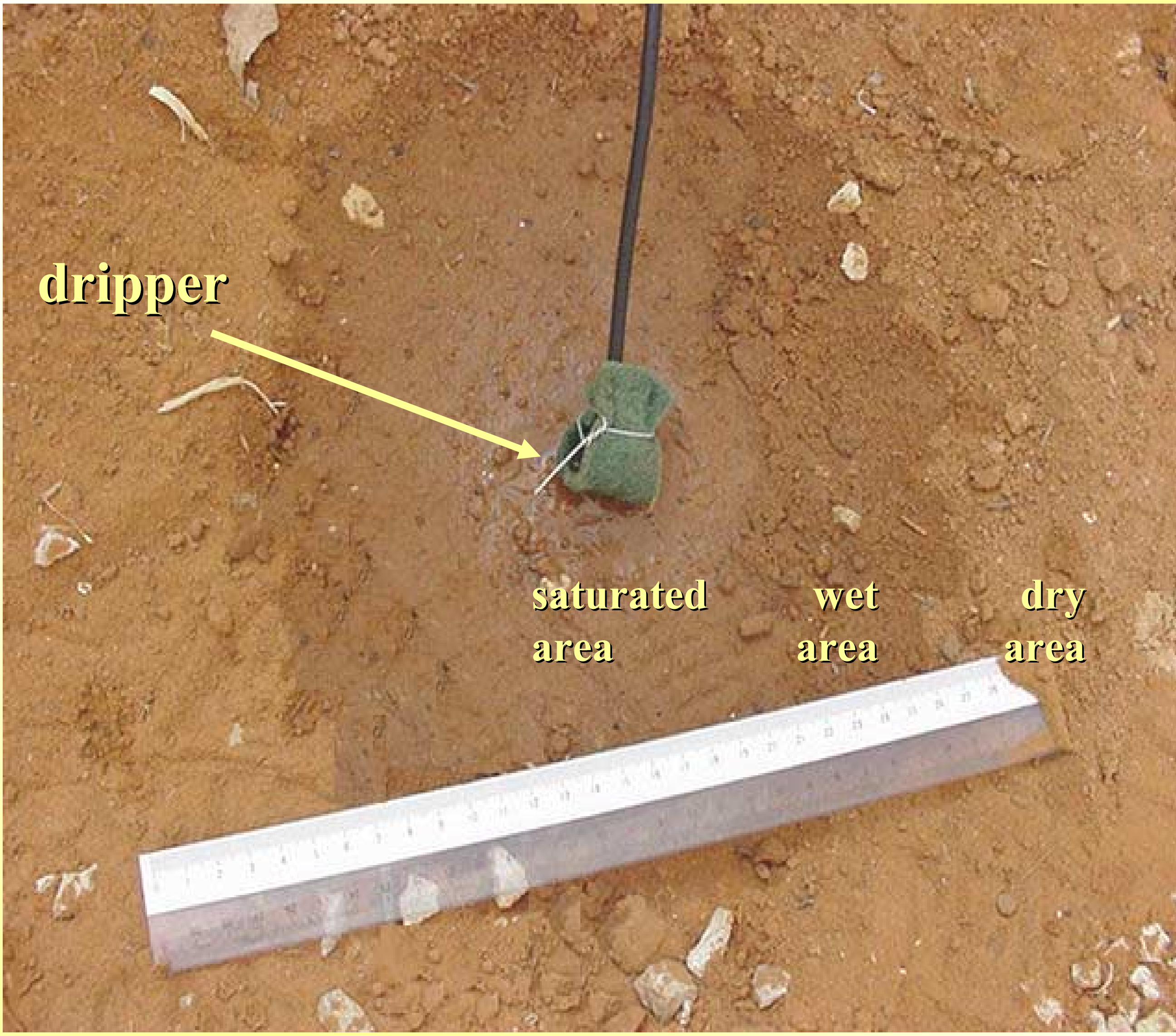


Peak ratio for infrared spectra (FTIR) of organic components solvent extracted (chloroform + methanol) from the alluvial soil (Gaaton) irrigated with fresh or effluent water (2-4 & 4-6 cm).

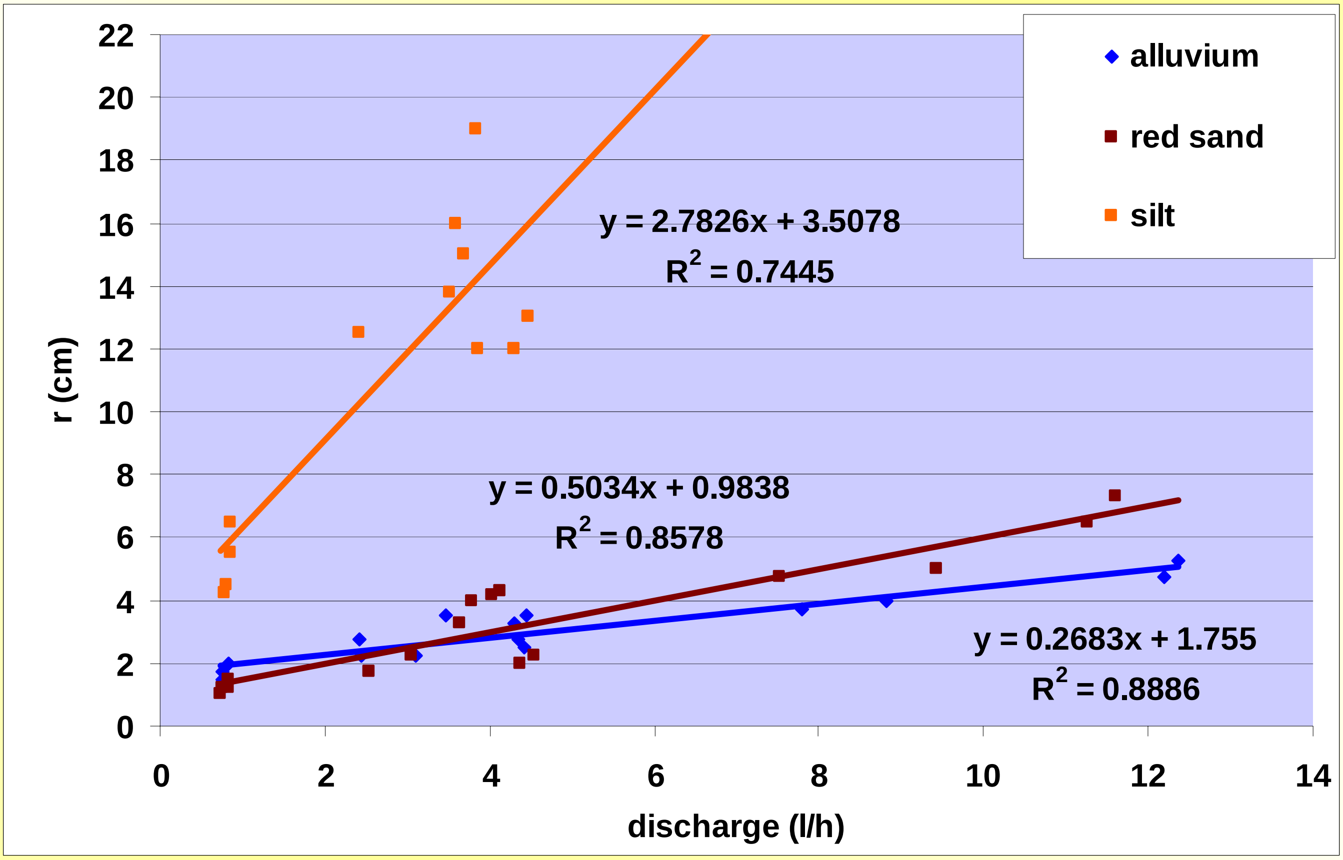



Fresh water
Effluents
A1
B1
A2
B2
15
30
45
75
20 cm
26 cm

Surface observation of the water distribution Regime – sandy soil



Saturated area radius vs. dripper discharge in sand, silt and alluvium soils irrigated with fresh water



Summary

1. Soil examined (sand, silt and alluvium) exhibited a diameter decrease of the saturated area when the soils were irrigated with effluents compared to fresh water.

2. The volumetric water content (at a depth of 0-10 cm) at different distances from the dripper was smaller in soils irrigated with effluent water compared to that of fresh water.

3. The wet areas in a sandy soil irrigated with a dripper supplying effluents shifted the penetration area and formed an unusual distribution regime in the soil indicating preferential flow.

Specific aims

1. To verify and characterize changes in water distribution regimes in soils irrigated with effluents in the field and the laboratory.

2. Evaluate the degree of hydrophobicity of soils irrigated with tap (fresh) water and effluents.

3. Characterize the humic substances (HS) extracted from soils irrigated with fresh water and effluents.

4. Characterize the hydrophobic materials extracted from soils irrigated with fresh water and effluents.

4. Water repellency was exhibited due to irrigation of various soils with effluents.

5. FTIR and ^{13}C-NMR, observations as well as elemental and potentiometric analyses indicated little or no differences in the composition and properties of extracted humic substances.

6. Solvent extracted materials from an alluvial soil (Gaaton) irrigated with fresh and effluent water exhibited the presence of highly hydrophobic aliphatic materials and some structured differences (0-2 cm only).

בצל ההרטבה הנוצר בקרקעות חול מושקות שפירים וקולחים

$\rho_b = 1.65\ g/cm^3$ (צפיפות גושית של החול)

$Q = 1\ l/h$ (ספיקת הטפטפת)

הידרופוביות בחול

מושקה קולחים

Silt irrigated with fresh water

Hydrophobicity in silt irrigated with effluents

Normal ponded area in alluvium irrigated with fresh water

Hydrophobicity in alluvium irrigated with effluents